Rentech

Fischer-Tropsch Fuels Analysis and Testing Results

1. Rentech Brochure.

2. Rentech Process Description.

3. Yakobson, D.L., Letter to Mr. R. Cross at California Air Resources Board, regarding analysis and testing results to CARB, 1984.

   A letter to CARB that provided fuel analysis and test data from high altitude tests by the Environmental Test Corporation, Aurora, Colorado.

4. Yakobson, D.L., Presentation to the California Energy Commission, California, 1991.

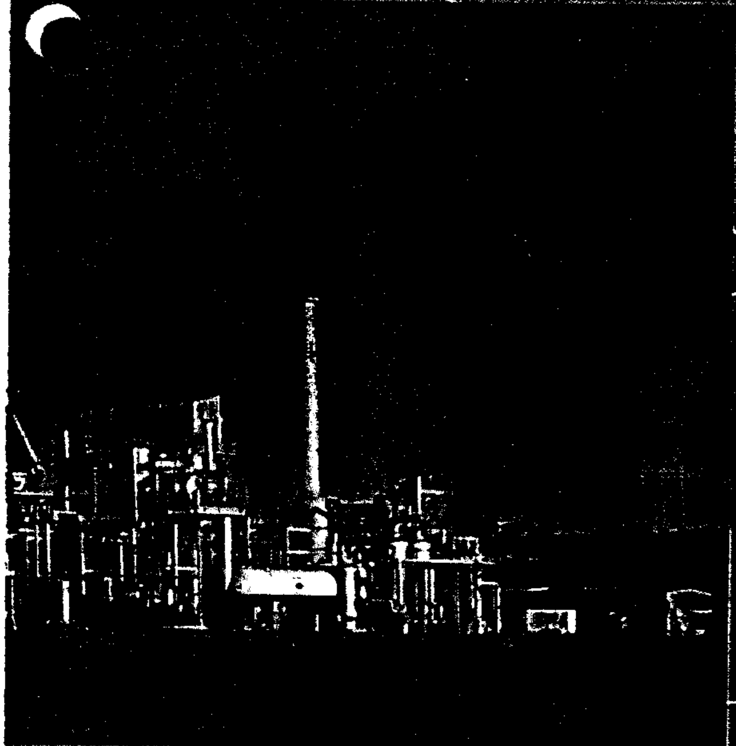
   A presentation that described the Rentech Fischer-Tropsch technology and the fuel quality produced, including the test results.

5. Engineering Evaluation Section, Mobile Source Division, "Emission and Fuel Economy Tests of Rentech Diesel Fuel", State of California, Air Resources Board, California, 1984.

   The test results and report by the State of California Air Resources Board. The test confirmed reductions in pollutants that has since been confirmed in many tests by others on Fischer-Tropsch diesel.

6. Winsor, Dr. Richard, Letter to Mark Hennesy at Detroit Diesel Corporation, Summary of Detroit Diesel Test performed on an 8V-92TA coach engine, 1989.

   Detroit Diesel evaluated the Rentech Diesel in their 8V-92TA coach engine using the federal heavy-duty transient emission test. This paper is the result of the tests. This testing became the basis for an SAE paper demonstrating the significant reduction in pollutants and the affect of oxygenates on diesel fuel emission profiles.



Technology Integration

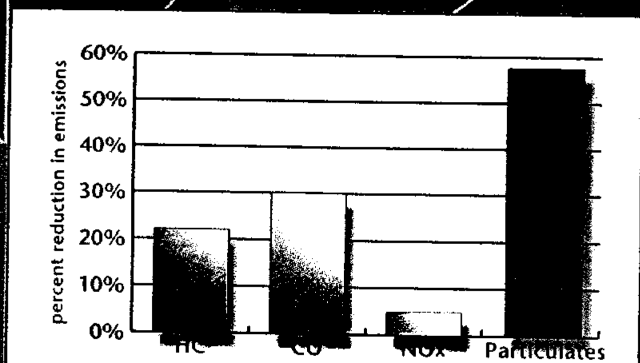
Rentech recently entered into a licensing agreement with Texaco Global Gas and Power (Texaco) for the Rentech Fischer-Tropsch technology. Under the license [illegible] Fischer-Tropsch technol[illegible] gasification technolo[illegible] [illegible] products such as naph[illegible] these [illegible] the Texaco gasifi[illegible] synthesis gas by par[illegible] [illegible] will be used [illegible] for the Rentech FT technology. These integrated technologies will conve[illegible] a broad range of feedstocks such as petroleum coke [illegible] oils and by-products generated in refineries [illegible] chemical plants into ultra-clean refined products. [illegible] available feedstock.

Premium, low-polluting products

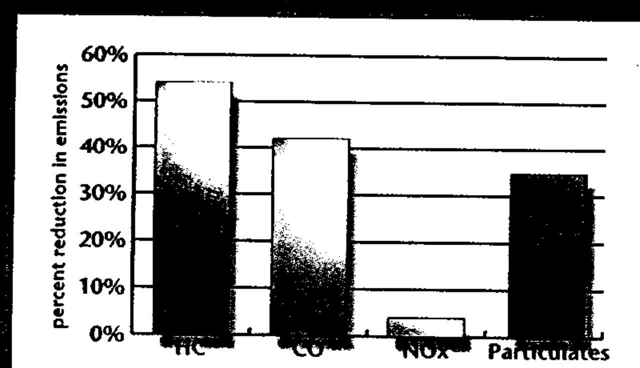
Detailed evaluation of the products produced by the Rentech FT process has to date centered to a great extent on the diesel fuel fraction due to its outstanding characteristics compared to currently available diesel. Rentech diesel meets all ASTM specifications and the proposed improved diesel characteristics suggested by the National Academy of Science (NAS). It is a premium fuel that is clean burning (low smoke), sulfur-free (reduced engine wear), high cetane (fast starting) and contains [illegible] (low pollution). Its use requires no engine or [illegible] modifications. Rentech's diesel fuel has been [illegible] Environmental Protection Agency specifications in light duty vehicle diesel [illegible] by the California Air Resources Board, El Monte, California [illegible] high altitude by the Environmental Testing [illegible] Aurora, Colorado. The two tests compared Rentech diesel fuel against No. 2 diesel fuel (Phillips Specification Diesel). Rentech diesel demonstrated significant reductions in harmful emissions. At high altitude, there is a [illegible]% reduction in particulates, 53% reduction in hydrocarbons and 41% reduction in carbon monoxide. Similar results are achieved at sea level, but with a [illegible]% reduction in particulate emissions.

Detroit Diesel Tests

Detroit Diesel Corporation conducted a limited particulate emission test on one of its heavy duty coach engines. The test showed a reduction of almost 35% in fuel related emissions [illegible] burning [illegible] Because [illegible] a substan[illegible] [illegible] expected [illegible] pattern [illegible] of its [illegible] convent[illegible] diesel [illegible] from crude oil. Blending [illegible] specification material to upgrade [illegible] diesel [illegible] may be the [illegible]



Emissions Results
Rentech Diesel vs. #2 Diesel
Sea Level (CARB) [illegible] GMC Sierra [illegible] DDA

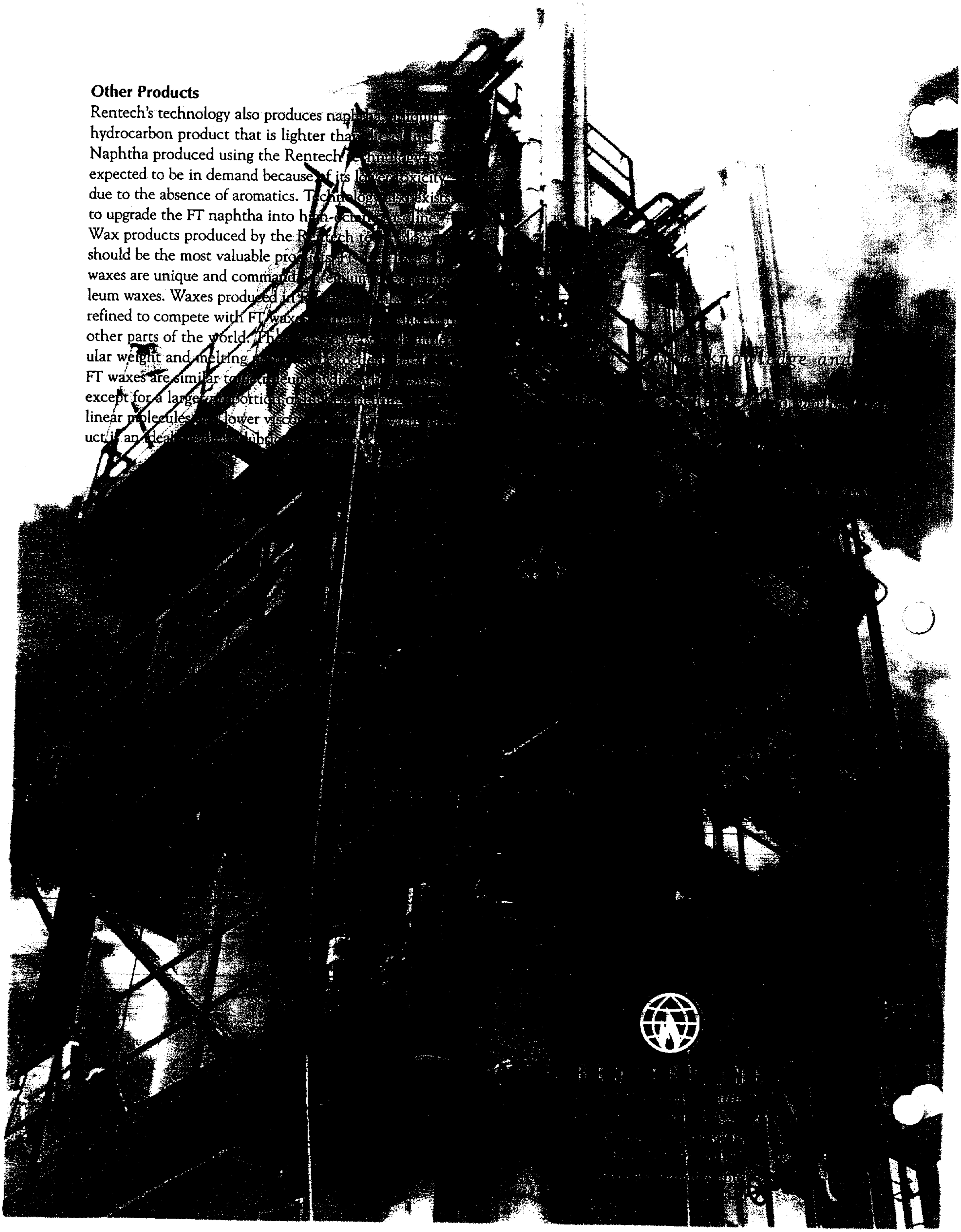


Emissions Results
Rentech Diesel vs. #2 Diesel
[illegible]

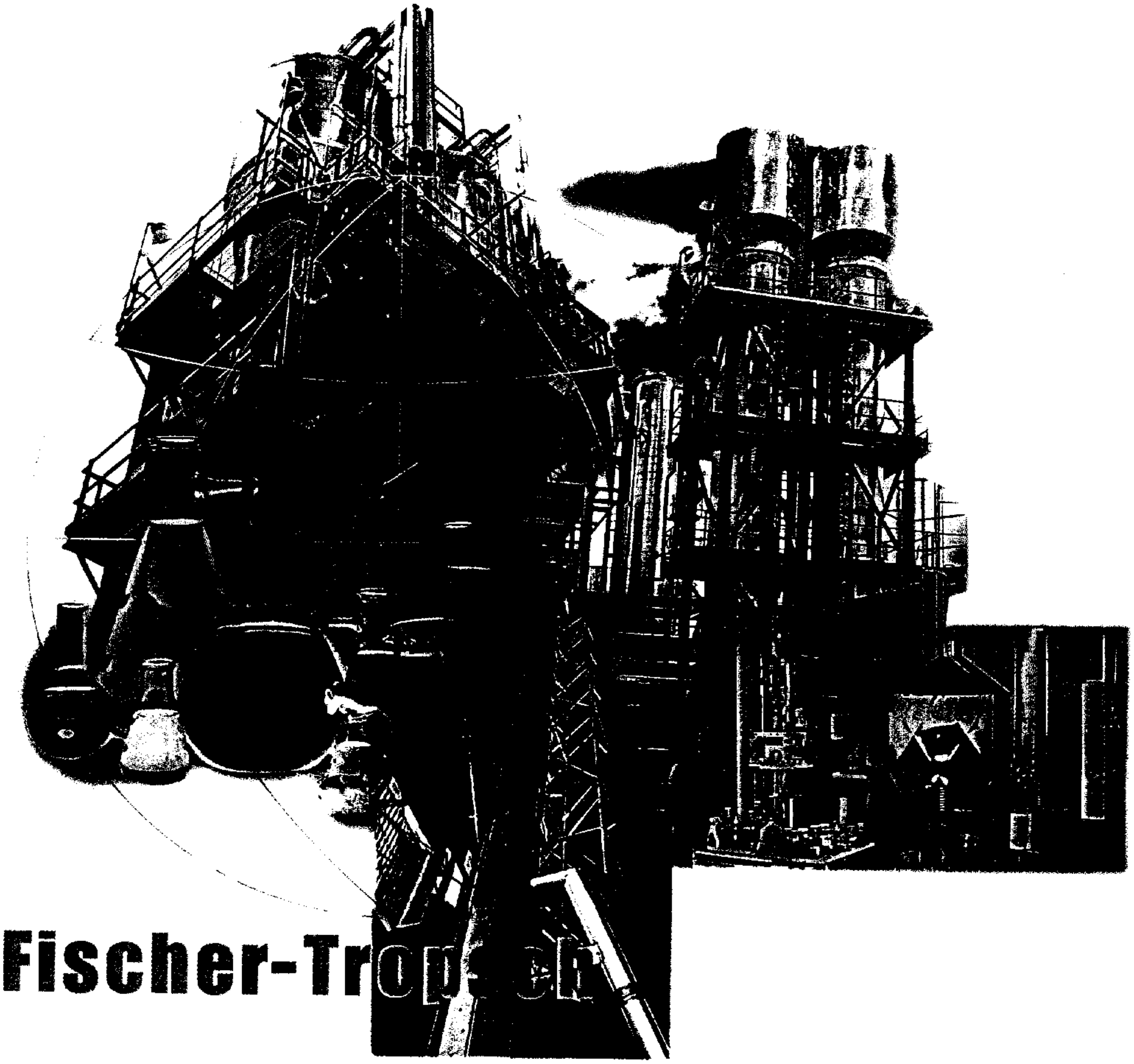
Other Products

Rentech's technology also produces naph[illegible] hydrocarbon product that is lighter tha[illegible] Naphtha produced using the Rentech [illegible] expected to be in demand because of its lo[illegible] toxicity [illegible] due to the absence of aromatics. Technology also exists to upgrade the FT naphtha into high-octane gasoline [illegible] Wax products produced by the Rentech technology should be the most valuable pro[illegible] waxes are unique and command [illegible] leum waxes. Waxes produced in [illegible] refined to compete with FT wax[illegible] other parts of the world. Th[illegible] ular weight and melting [illegible] excellent [illegible] FT waxes are similar to [illegible] except for a large [illegible] portion [illegible] linear molecules [illegible] lower visc[illegible] uct is an ideal [illegible]

[illegible] knowledge, and



RENTECH



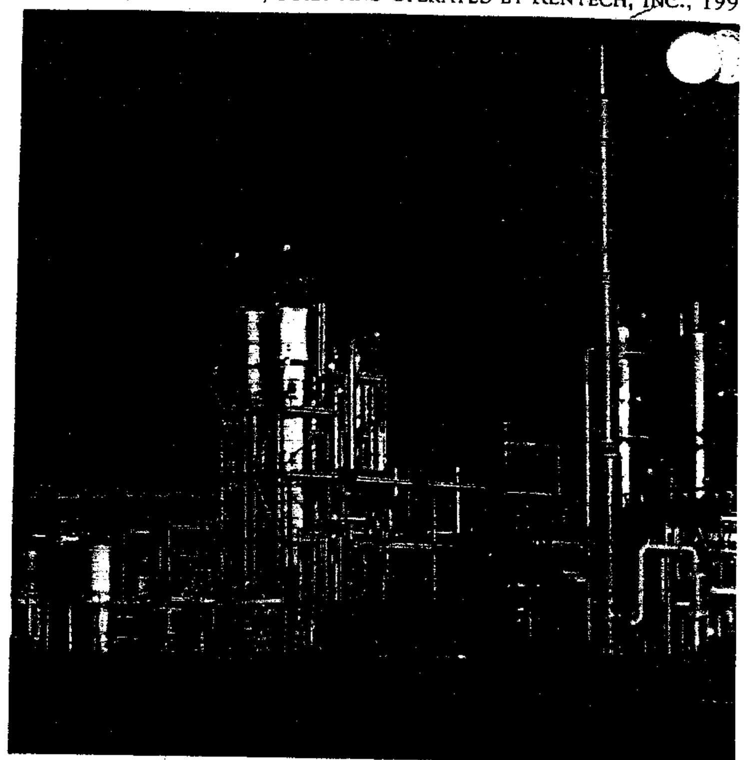
Fischer-Tropsch

Converting natural gas, coal and refinery bottoms to super clean fuels, products and chemicals

Rentech—
a leader in Fischer-Tropsch technology

- *Founded in 1981*
- *Seventeen iterations of catalyst development*
- *Five pilot plants*
- *Experienced in reactor design*
- *Experienced in technology integration*
- *System efficiency optimized*
- *Utilizes a wide range of feedstocks*
- *Provide engineering support*
- *Provide feasibility analysis*

SYNHYTECH PLANT—AN INTEGRATED, FULL-SCALE FT PLANT DESIGNED, FABRICATED, BUILT AND OPERATED BY RENTECH, INC., 199



Rentech, Inc., a publicly-traded Colorado corporation, was incorporated in December 1981 to develop and market its technology for converting carbon-bearing materials into premium hydrocarbon products. The technology is based, in part, upon process steps proven in other applications; however, the Rentech process is unique and certain parts of the technology are proprietary to Rentech. Rentech's is one of four Fischer-Tropsch-based (FT) technologies that have operated at commercial scale. Moreover, Rentech is the only company in the world licensing an iron-based catalyst in a slurry reactor suitable for converting a wide range of carbon-bearing materials into premium hydrocarbon products (see Figure 1).

Commercial Plant Experience

The Company has invested over 60 man-years in its technology for efficiently converting a wide range of carbon-bearing feedstocks, thereby expanding the market for potential projects. Rentech has operated five pilot plants, and an integrated commercial-scale FT plant. Rentech is one of only three companies worldwide that has commercial plant experience in design, construction and operation. The Company designed, fabricated, installed and operated the largest FT slurry reactor in the world outside of South Africa. Rentech also has experience in catalyst manufacturing, development and life-cycle testing. Unlike cobalt-based FT technologies, the iron-based catalyst has a wide range of operational H_2:CO ratios required to convert a broad range of feedstocks.

Patented Technology

Rentech has two decades of development experience, with nine patents issued and more pending. Rentech holds patents on iron catalyst preparation and catalyst induction in a slurry reactor. Rentech also holds patents for use of products made by iron-based FT catalyst and certain patents for increasing carbon conversion efficiencies.

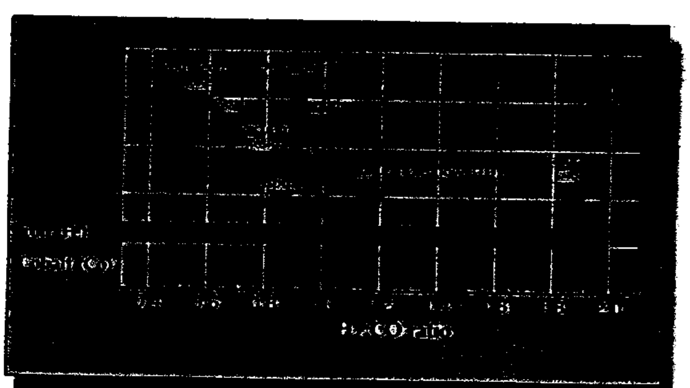


FIGURE 1: FEEDSTOCKS—FT CONVERSION CATALYSTS

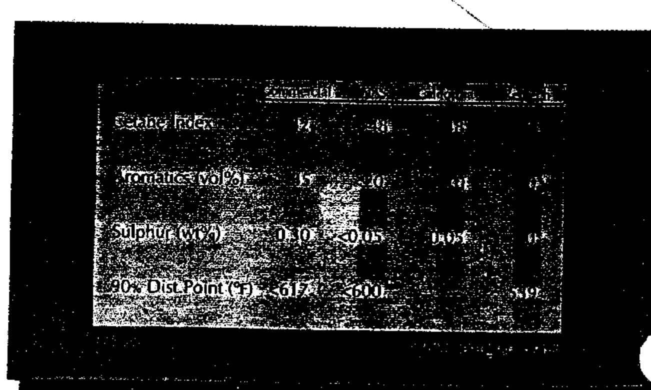


FIGURE 2: KEY DIESEL FUEL CHARACTERISTICS

RENTECH, INC.

January 1999

RENTECH, INC.
Gastoliquids.com

General

Gas-To-Liquids (GTL)

Rentech, Inc. incorporated in December 1981, is a publicly-traded Colorado corporation. The Company was formed to develop and market its technology for the conversion of carbon-bearing materials into premium liquid hydrocarbons. The technology is based in part upon process steps that have been proven in other applications; however, the Rentech process is unique and certain parts of the technology are proprietary to Rentech. Rentech's process is one of four Fischer-Tropsch based technologies that has operated at commercial scale and one of only two companies in the world offering an iron-based catalyst in a slurry reactor which is suitable for converting a wide range of carbon bearing materials.

The principal products of the Rentech GTL process are a clean-burning premium-grade diesel fuel that is suitable for vehicle use without any engine modifications; naphtha's useful as feedstock for chemical processing and for refining into varnishes and mineral spirits; and, waxes which can be used in hot-melt adhesives, inks and coatings, and a variety of other wax-based products. In the absence of a wax market, the waxes can be thermally or hydro-cracked at the plant site and the entire product stream could be sold as a superior diesel fuel except for a minor quantity of naphtha.

In October 1998, Rentech entered into a licensing agreement with Texaco Group, Inc. to exploit Rentech's gas conversion technology on a worldwide basis (See **Present Licenses**).

THE RENTECH PROCESS DESCRIPTION

Rentech's technology is based upon the Fischer-Tropsch process that was originally developed in Germany during the 1930's to create synthetic fuels. When low-priced petroleum products became readily available after World War II, Fischer-Tropsch conversion research was essentially abandoned. The Arab oil embargo of 1973 created fuel shortages, and that crisis served to renew interest in Fischer-Tropsch processes. Research by Rentech personnel was conducted at the Naval Weapons Center in China

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Lake, California and later at the Solar Energy Research Institute in Golden, Colorado. Based in part on those efforts, Rentech developed its own conversion process including a proprietary catalyst that is essential for the use of its technology.

The primary feedstock sources for conversion plants using the Rentech technology is natural gas from gas resources that cannot be produced due to their remote location; gas wells containing diluents such as carbon dioxide or nitrogen; oil wells that flare associated gas; or synthesis gas, a mixture of hydrogen and carbon monoxide, produced by gasification of coal or low value oil refinery residuum.

The Rentech Gas-to-Liquids (GTL) technology can convert any carbon bearing material, including but not limited to natural gas, coal and refinery bottoms to premium quality liquid and solid hydrocarbon products. A series of chemical process steps, one of which is the Fischer-Tropsch reaction, is used to carry out the conversion process. Plants that use the Rentech technology may be designed to produce from several hundred up to several thousand barrels per day of product. The plants are designed to use existing off-the-shelf technology to the greatest extent possible.

For the Rentech process, the initial and most expensive process step is the production of the required synthesis gas, a mixture of carbon monoxide (CO) and hydrogen (H_2), from the feedstock source. The chemical conversion to make synthesis gas or syngas can be carried out by various methods – steam methane reforming (SMR), partial oxidation (POX), or autothermal reforming (ATR). The decision on what method is selected is usually made on a project by project basis. While the use of POX or ATR is more thermally efficient and provides for a more elegant process flow arrangement, the anticipated increase in capital costs to produce the required oxygen may make it more expensive than SMR or POX. All the above mentioned syngas approaches are well-developed and widely-used and the necessary equipment is available worldwide from a number of companies.

If natural gas is used as the feedstock supply, the first step is to remove any contained sulphur. This is normally done by preheating the natural gas to approximately 750° F and passing it through a zinc oxide bed. The natural gas is then fed to the partial oxidation unit (POX) or autothermal reformer (ATR) where a stream of relatively pure oxygen is added to support the conversion of the methane to synthesis gas. For Rentech's GTL process air or enriched air can be used in lieu of oxygen, however, overall process yields will be reduced relative to pure oxygen. If the feedstock is a solid such as coal or refinery bottoms or a liquid such as Orimulsion ™ then partial oxidation is the only viable syngas preparation technology. ATR and SMR both use catalysts which cannot process heavy liquids due to carbon formation. Production of syngas from solids requires the use of POX. Upon exiting the POX or ATR, the syngas is cooled to condense most of the entrained water prior to the Fischer-Tropsch reactor for conversion to liquid hydrocarbons.

The next major process step is the synthesis reaction, the key chemical reaction that converts the hydrogen and carbon monoxide into a mixture of hydrocarbon molecules. Known since the nineteen twenties, the Fischer-Tropsch reaction is represented generally by the equation:

Fischer-Tropsch $2nH_2 + nCO \rightarrow (\text{--}CH_2\text{--})_n H_2O + \text{heat}$ (1)

In addition, for iron-based catalysts such as the one used by Rentech the water gas shift reaction also takes place:

Water Gas Shift $H_2O + CO \rightleftarrows H_2 + CO_2$ (2)

Because an iron-based catalyst exhibits high water gas shift activity, Equation (2) it can be used to convert synthesis gas which has a H_2 to CO ratio less than 2:1 as required by Equation (1) for the same extent of reaction. This allows for the conversion of carbon bearing materials such as coal and refinery bottoms which are deficient in hydrogen.

Modern cobalt catalysts normally do not have any appreciable water gas shift activity. Therefore the syngas must have the 2:1 H_2 to CO ratio for maximum efficiency. For this reason, cobalt catalysts are not ideal candidates for conversion of carbon bearing materials other than natural gas. Also, any sulphur compounds that may reach the cobalt catalyst can adversely impact its life and performance. Iron catalyst can tolerate small amounts of sulphur but in such event the catalyst cannot be regenerated.

Because iron F-T catalysts exhibit the water gas shift activity which converts some of the carbon monoxide to carbon dioxide has in the past produced lower hydrocarbon yields than cobalt-based catalysts. However, it appears that Rentech, by the use of its patented process steps, has overcome this problem and achieves yields comparable to cobalt based F-T technologies.

Since inception, Rentech has focused on the three-phase slurry reactor, rather than the fixed-bed reactor design for the F-T synthesis step. The fixed-bed design (used by SASOL in its ARGE Reactors and by Shell in its Bintulu plant in Malaysia) has low catalyst attrition and is relatively simple in concept. However, for the fixed bed reactor, the catalyst must be contained in small-diameter tubes to allow removal of the heat generated by the exothermic Fischer-Tropsch reaction. In addition, standby reactors are required because the required F-T catalyst cannot be replaced or reactivated while the reactor is on line. Therefore, the reactor subsystem can become quite expensive.

The desirable operational characteristics of the slurry reactor is its efficient heat transfer which maintains the catalyst at a constant temperature with a small number of cooling tubes and the ability to change out catalyst while on line. These key characteristics make it much more economical for smaller scale commercial plants.

Results obtained by Rentech, using the slurry reactor, both at pilot plant and commercial scale, demonstrated excellent cooling control of the exothermic F-T reaction. In fact, the six-foot in diameter commercial scale reactor designed, built and operated by Rentech was maintained at less than a 2° F temperature gradient throughout the reaction zone.

The Fischer-Tropsch process end-products are chiefly straight-chain hydrocarbons together with water and a smaller quantity of alcohols. The hydrocarbons produced by Rentech's process range from C_1 to C_{100}- from paraffins and olefins, alcohols to ketones to acids. The product slate depends on the catalyst used and the operating conditions selected. The process plant can be designed so that the products of the synthesis reaction are either collected by a relatively simple condensation system as "crude oil" or are separated by conventional distillation means into five major fractions: waxes, a water/alcohol mixture, clean burning diesel fuel, naphtha, and tail gases. The water/alcohol mixture may be recycled for reprocessing or distilled to yield separate fractions of mixed alcohols and water that can be further treated to render it potable.

The remaining three fractions if separated – waxes, diesel, and naphtha – comprise the major marketable products from the plant. If not fractionated and the end product is a sulphur-free (sweet) very light crude oil plus wax which can be readily thermally cracked on site.

A portion of the tail gases are recycled to the POX or ATR inlet to improve overall carbon conversion efficiency with the remainder used to meet process requirements. An innovation developed by Rentech for which a patent has been applied for is the separation of hydrogen from the tail gases for recycle to the F-T synthesis reactor inlet. By this step, which is applicable to both gaseous and solid carbon bearing feedstocks, yields are increased by as much as eleven percent and allows feedstocks such as coal and low value refinery residues with high carbon to hydrogen ratios can be efficiently processed.

In general terms, based upon a feed gas pressure of approximately 225 psig and if operated in the high wax mode, the F-T product split would be:

(i) For the standard four-products slate:

Naphtha (C_5-C_4)	6	vol%
Diesel (C_{10}-C_{19})	18	vol%
Soft wax (C_{20}-C_{33})	34	vol%
Hard wax (C_{34}+)	42	vol%

(ii) If the soft wax was cracked to diesel and naphtha to produce a three-product slate:

Naphtha (C_5-C_9)	13	vol%
Diesel (C_{10}-C_{19})	44	vol%
Hard wax (C_{34}+)	43	vol%

(iii) If both the hard and soft wax were cracked to give a two-product slate:

Naphtha (C_5-C_9)	23	vol%
Diesel (C_{10}-C_{19})	77	vol%

If required, the conversion process in plants using the Rentech technology can be easily simplified to only produce a light sweet crude oil for sale to refineries.

Process End Products

The detailed evaluation of the products, to date, has centered, to a great extent, on the diesel fuel fraction due to its outstanding characteristics when compared to currently available diesel.

The Rentech diesel meets all ASTM specifications (see Table 1) and the proposed improved diesel characteristics suggested by the National Academy of Science. It is a premium fuel that is clean-burning (low smoke), sulphur-free (reduced engine wear), high-cetane (fast starting) and contains no aromatics (low pollution). Its use does not require any engine or vehicle modifications.

TABLE 1
COMPARISON OF
FUEL CHARACTERISTICS

Fuel Characteristics	Commercial Diesel	NAS Recommendations (1)	Rentech Diesel
Cetane Index, Minimum	46	>48	67
Sulfur, % wt max	0.35	<0.25	<0.001(2)
90% Distillation	617	<600	571
Aromatics % vol	33	<20	0.0

(1) National Academy of Science – Diesel Technology 1981
(2) Analyses were below limits of detection

Rentech's diesel fuel has been vehicle-tested to Environmental Protection Agency specifications in light duty vehicles at sea level by the California Air Resources Board, El Monte, California, and at high altitude by the Environmental Testing Corporation, Aurora, Colorado. The two tests compared Rentech's diesel fuel against commercial No. 2 diesel fuel (Phillips Specification diesel). The Rentech diesel fuel demonstrated significant reductions in harmful emissions. At high altitude, there was a 35% reduction in particulates, 53% reduction in hydrocarbons and 41% reduction in carbon monoxide. At sea level, similar results were achieved, but with a 56% reduction in particulate emissions.

Detroit Diesel Corporation conducted a limited particulate emission test on one of its heavy duty coach engines. That test indicated a reduction of almost 35% in fuel-related emissions when using Rentech's diesel fuel as compared to commercial No. 1 Diesel fuel, which is a much cleaner burning fuel than the more widely used No. 2 Diesel fuel. Based upon the absence of aromatics in the Rentech diesel fuel, a substantial reduction in the amount of carcinogens released is also expected.

Rentech applied for and received three U.S. patents on the use of its F-T diesel fuel by itself or as a blend stock with conventional diesel fuels produced from crude oil to reduce harmful emissions. Blending of Rentech's diesel fuel with off-specification material to upgrade such material to meet diesel specification may be the optimum usage.

Fischer Tropsch diesel fuels produced by Sasol have been used extensively in South Africa for many years, without adverse effects. The diesel fuel, which can be added directly to existing commercial diesel fuels, meets all ASTM requirements and, therefore, can be sold commercially in the United States.

Rentech's technology also produces naphthas, which are liquid hydrocarbon products that are lighter than diesel fuel. Naphthas are used extensively in manufacturing processes for products as diverse as paint, printing ink, polish, adhesives, perfumes, glues and fats. Naphthas produced using the Rentech technology are expected to be in demand due to their lower toxicity due to the absence of any aromatics. Technology also exists to upgrade the F-T naphtha into high-octane gasoline.

The wax products produced by the Rentech technology should be the most valuable products; however, the wax market is very small. Fischer-Tropsch waxes are unique and command a premium over petroleum waxes. World demand for the high-melting point Fischer-Tropsch waxes has historically been approximately 85 million pounds per year at an average price of $0.60 – 0.70/lb. ($U.S.). Waxes produced from a Rentech plant can be refined to compete with other Fischer-Tropsch waxes currently produced in other parts of the world. They have a very high molecular weight and melting point, and have excellent hardness. Fischer-Tropsch waxes are similar to petroleum hydrocarbon waxes with the exception that they have a higher proportion of higher melting point linear molecules and have lower viscosity.

The U. S. alone consumes approximately 25-30 million pounds of Fischer-Tropsch waxes each year, approximately 300 barrels per day.

Plasma - Reforming Technology

On August 31, 1998, Rentech, announced that it had entered into a Joint Demonstration Project (JDP) with Thermal Conversion Corp. (TCC). Thermal Conversion Corp., with headquarters in Kent, Washington, is wholly owned by EnterTek Partners, an investment group managed by Scientific Advances, Inc. (SAI), a subsidiary of Battelle Memorial Institute. EnterTek Partners is composed of major natural gas companies in the United States, including Brooklyn Union Gas System, Columbia Gas System, Consolidated Natural Gas, Enron Corporation, Equitable Resource Company and Southern California Gas Company.

The purpose of the currently ongoing JDP is to evaluate the use of the TCC plasma-reforming technology which uses TCC's proprietary high-power, induction-coupled plasma torch and high-temperature reactors to convert natural gas into a tailored synthesis gas, suitable for use by Rentech's GTL process. As discussed elsewhere in this report, synthesis gas, a mixture of carbon monoxide (CO) and hydrogen (H_2) is an intermediate step for the conversion of carbon bearing materials to liquid hydrocarbon for all GTL processes. Successful development of the Thermal Conversion Corp plasma-reforming technology will eliminate the need for oxygen from either an expensive oxygen plant or in lieu of an oxygen plant using air or enriched air as the source of the required oxygen. If air or enriched air is used as the source of the required oxygen for the generation of the syngas this results in larger plant equipment and lower product yields.

During the two phase, sixteen week project to be funded by Rentech, the viability of using the TCC plasma- reforming technology in GTL plants will be tested for verification at pilot plant scale and capital costs will be developed.

Upon successful completion of the Project, Rentech has the right to receive a nonexclusive license to use and sublicense to third parties the TCC plasma-reforming technology and to receive a portion of any future license fees and royalties received by TCC for use of their technology in any other GTL projects. TCC will provide the plasma system when used with any GTL process including Rentech's.

TCC has completed Phase I - The Application Analysis for the integration of its proprietary plasma-reforming technology to produce syngas for Rentech's Gas-to-Liquids (GTL) process with the goal of maximizing liquid fuels production. The initial results appear to be very positive.

On November 24, 1998, Rentech announced its intent to proceed with the second phase of the Joint Demonstration Program, the actual physical testing of the plasma reforming process in Thermal Conversion Corp's 1MWe facility, to confirm the results developed during the initial phase of the program.

Rentech and Thermal Conversion Corp believe the benefits of plasma-reforming compared to conventional syngas production processes for gas conversion plants of less than 5,000 barrels per day are;

- A reactor easily controlled to yield the desired syngas composition;
- Elimination of the requirement for an oxygen source to be supplied by air compression or an expensive oxygen plant.
- A relatively simple system for integration with the F-T process; and
- The potential for processing low-value or waste feedstocks.

F-T Technology Patents

To date, Rentech has been granted nine patents with five more patent applications pending covering certain process applications, products produced, and materials used in its process. Additional patent applications regarding Rentech's ongoing efforts with TCC on plasma-reforming and with ITN/ES on the ceramic membranes are anticipated to be filed shortly.

Synhytech Plant

The first commercial scale gas conversion plant to utilize Rentech's technology was the Synhytech Plant. In 1985, Fuel Resources Development Company (Fuelco), a wholly-owned subsidiary of Public Service Company of Colorado (PSCo), evaluated Rentech's technology and in 1986 Rentech granted Fuelco the right to obtain an option to license the technology. In 1990, Fuelco began construction of the first full-scale conversion plant, located near Pueblo, Colorado. This plant, called the Synhytech Plant, was constructed at a cost in excess of $20 million and was designed to use the gas from a landfill as its feedstock (landfill gas is typically comprised of methane and carbon dioxide). The plant was designed and built by an independent contractor for Fuelco to produce approximately 235 barrels of liquid hydrocarbons per day. The Synhytech Plant began start up operations and first produced liquid hydrocarbons in January 1992. Rentech's technology, including its synthesis reactors and catalyst, performed as expected and the technology was again confirmed now at commercial scale. Fuelco was unable, however, to produce enough gas from the landfill to operate the plant, and operations were suspended in May 1992.

In mid-1992, PSCo, as part of its decision to return its core business of producing and selling electricity, decided to divest itself of several subsidiary businesses, including its real estate development business and Fuelco (including its Synhytech operations). After extensive negotiations, PSCo and Fuelco transferred all interest in the Synhytech plant to Rentech in May 1993, together with associated equipment and assets, including $650,000 in cash and all the machinery, equipment and other assets assembled by Fuelco in Boulder, Colorado to manufacture Rentech's proprietary catalyst.

In order to use the plant to further demonstrate the viability of its technology at commercial scale, Rentech converted the Synhytech plant during 1993 to use only natural gas rather than landfill gas. Rentech corrected and resized several items of equipment and other associated hardware, and modified several aspects of the engineering design used by Fuelco.

In accordance with the Company's plan to demonstrate the technical reliability of its technology in a commercial scale plant, the modified Synhytech plant was operated successfully in a continuous state for three weeks during the summer of 1993. The results of the demonstration program completed in August 1993 were positive. During the demonstration phase, the plant operated at design specifications, produced the expected range of hydrocarbon products, and achieved the design conversion ratios anticipated for Rentech's proprietary catalyst used in the conversion process. Both the selectivity and activity of Rentech's proprietary catalyst remained constant over the operating period. Mass balance between the input and output of the synthesis reactor was within one percent of expected projections. Measured product yields were higher than initially projected and were biased toward the heavier molecular weight products. As planned, the plant was then shut down pending a decision by Rentech's management about its final disposition. The technical data collected and initial product test results demonstrate that the process was feasible for commercial exploitation. In March 1995, the Synhytech Plant was sold to the Company's Indian licensee for a 300 barrel per day process plant to be located in northeastern India.

Present Licenses

Several licenses for use of its technology have been granted by Rentech. The licenses authorize third parties to construct conversion plants utilizing the Company's technology. The license agreements are granted in exchange for license fees, engineering design fees, and continuing production royalties based either upon a percentage of gross proceeds from the sale of liquid hydrocarbons or other products produced through use of the Rentech technology or based upon some other measure of product value. Licenses may grant either exclusive or non-exclusive rights to use the technology in identified countries or other geographic areas. The license fees and terms are individually negotiated and vary among licensees.

In September 1992, Rentech granted to ITN. Inc., a Colorado company, the exclusive right to market the Rentech technology in the country of India to potential owners of Rentech process plants. If ITN identifies parties who obtain a license from Rentech and build a plant or plants in India using the Rentech technology, a share of Rentech's royalty, license fee or other compensation from such plants will be transferred to ITN.

On October 8, 1998, Rentech entered into a licensing agreement with Texaco for the Rentech technology. Under the license, Texaco will have the right to use Rentech's gas-to-liquids technology in combination with Texaco's proprietary gasification technology to produce liquid hydrocarbon products such as naphtha, fuel and specialty products.

The Texaco gasification technology, which produces synthesis gas by partial oxidation of carbon-based substances, will be used to generate the synthesis gas feedstock for the Rentech's technology. The combination of these technologies will allow for the use of a broad range of feedstocks such as petroleum coke, residual oils and by-products generated in refineries and chemical plants.

Under terms of the agreement, Texaco was granted an exclusive, worldwide (except in India) license to use and sublicense the Rentech Process Technology in projects where solid and liquid hydrocarbons are used as feedstocks for the generation of syngas in a gasification process such as the proprietary Texaco Gasification Process. Rentech retains the right to license for 100 percent natural gas feedstock. However, Texaco was also granted a worldwide (except for India) non-exclusive license to use but not sublicense the Rentech technology for the conversion of 100% natural gas.

Gas-to-Liquids Business Approach

The Company's business is the licensing of the Rentech conversion technology, including sale of its proprietary catalyst, in exchange for license fees and ongoing royalties on the production of liquid hydrocarbons from conversion plants that use the technology. Rentech will provide engineering design and technical services and startup operational support services on a fee basis for licensed plants. In addition, Rentech reserved the right to engineer and construct the synthesis gas conversion reactor modules that are essential to use of the technology in conversion plants. The Company may also make investments to participate in the ownership of future plants developed by licensees.

GTL Summary

Rentech's patented and proprietary GTL technology has as its key points;

- Efficiently converts a wide range of carbon bearing feedstocks;
- Produces an adjustable slate of high-quality hydrocarbon fractions;
- Obtains yield efficiencies equivalent to cobalt based F-T catalysts: and
- Utilizes a low cost F-T synthesis step – the slurry reactor.

CONTACT:

RENTECH, INC.
1331 17th Street, Suite 720
Denver, Colorado 80202
Phone: (303) 298-8008
Fax: (303) 298-8010
E-mail: Rosrntk@aol.com

RENTECH, INC.

March 13, 1984

Mr. R. Cross
California Air Resources Board
9528 Telstar Avenue
El Monte, California 91731

Dear Bob:

It was a pleasure talking to you today regarding the Rentech, Inc. diesel fuel. Per your request, I have enclosed copies of our diesel fuel specification data and the results of the vehicle testing.

As I mentioned, the economics of our process are primarily dependent upon the cost of the raw feed stock which is methane gas. However, we believe that such sources can be acquired at reasonable cost either from shut-in or flared gas wells or municipal sewage treatment plants. This would allow us to price our product on a competitive basis with current supplies.

We anticipate having our fuel tested by the Regional Transportation District here in Denver in the near future and hopefully, with a timing adjustment, our previous testing did not involve any engine adjustments, we expect to further improve the emission results and hopefully provide greater fuel economy than commercial diesel.

I hope that this data will be of interest to you and we can work together in the future.

Very truly yours,

Dennis L. Yakobson
President

DLY/ldk

Enclosures

1620 Market Street Suite 401 • Denver Colorado 80202 • 303/571-4158

RENTECH, INC.

Table 1.

ASTM D975 Specifications for Automotive Diesel
Fuel as Compared to Rentech Diesel

Fuel Characteristic	No. 1 Diesel	No. 2 Diesel	Rentech Diesel
flash point °F, minimum	100°F	125°F	171°
cloud point	(a)	(a)	(a)
Carbon residue 10% Btm, % max	.15	.35	not detectable
Viscosity at 100°F, CST	1.3-2.4	1.9-4.1	2.01
Copper Corrosion	No. 1 min/ No. 3 max	No. 1 min/ No. 3 max	No. 1a
Sulphur, wt. % max	0.5%	0.5%	not detectable
Ash % by wt., max	.01%	.01%	not detectable
Cetane number, minimum	40	40	73
90% Distillation °F, maximum	550°F	540-640°F	588°F

Table 2.

#2 Diesel Fuel

Fuel Characteristics	NAS(1) Recommendations	Weighted Average For Colorado	Rentech Fuel
Cetane Number, minimum	>48	47.07	73
Sulphur (%wt.), maximum	<.25%	0.341%	not detectable
90% Distillation	<600°F	591.47°F	588°F
Aromatics	<20%	33.8%(2)	3.9%(3)

(1) General Property limits for improved diesel fuel recommended by the National Academy of Sciences from their publication, Diesel Technology.

(2) p. 76 Diesel Emissions: Their Formation, Impacts and Recommendations for Control published by the Colorado Department of Health.

Table 2. (Continued)

(3) Aromatic content maximum, actual % value is expected to be lower.

Table 3.

Energy Content No. 2 Diesel

	Average for Colorado	Rentech
BTU's/lb.	18,300	20,646
API Gravity	34-35°	51°
Specific Gravity	.8550-.8498	.7753
BTU/Gallon (a)	130,335-129,543	133,337

(a) [8.33] [Specific Gravity] [BTU/LB] = BTU/Gallon

In summary Rentech diesel fuel compared to specification diesel and to diesel sold in Colorado is:

(a) of a higher quality

(b) should have significantly lower emissions

(c) should provide higher miles/gallon

(d) should meet all proposed emission specifications

VEHICLE TEST

Vehicle: 1983 VW Quantum Turbo Diesel

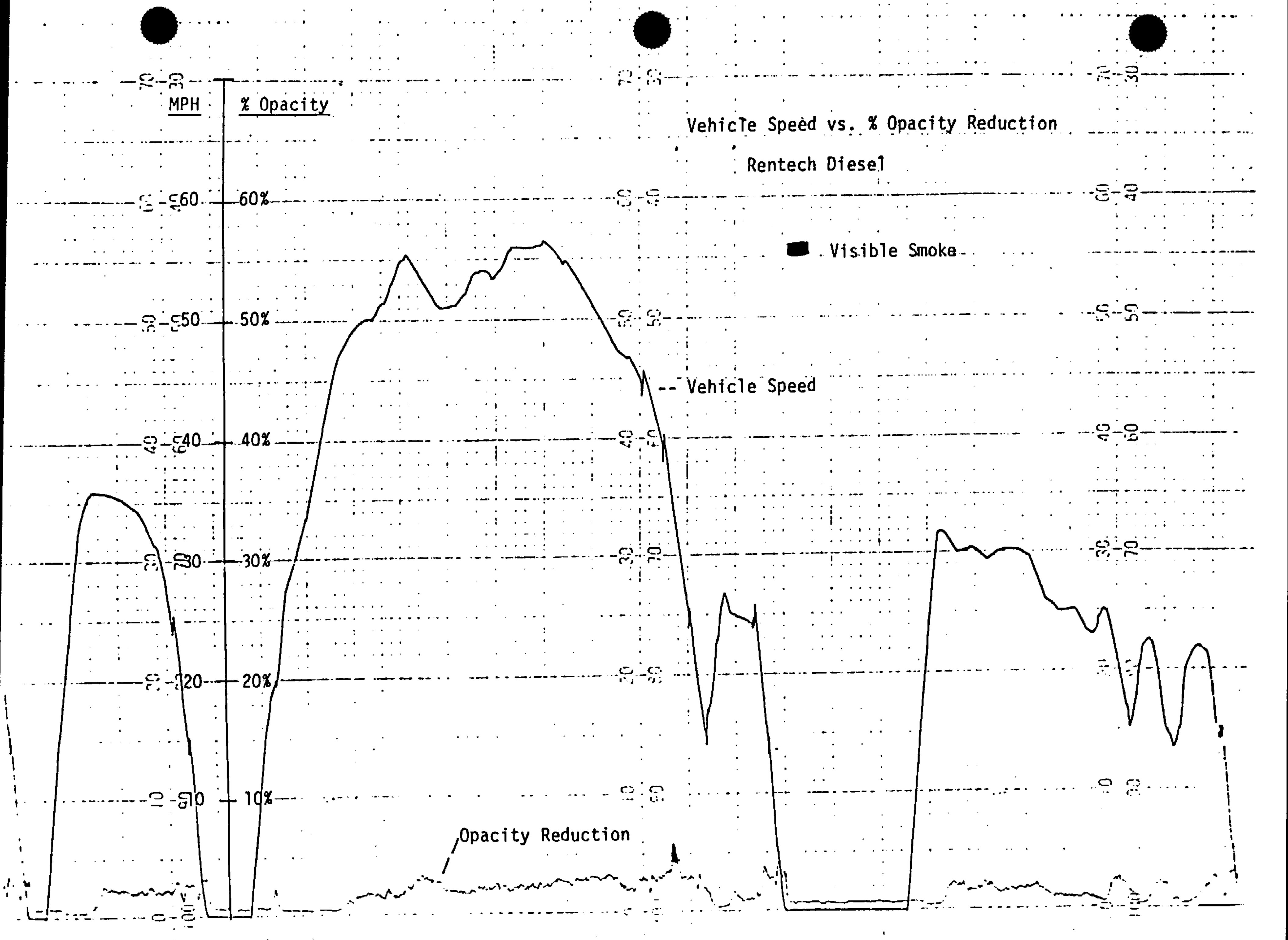
Date: January 27, 1984

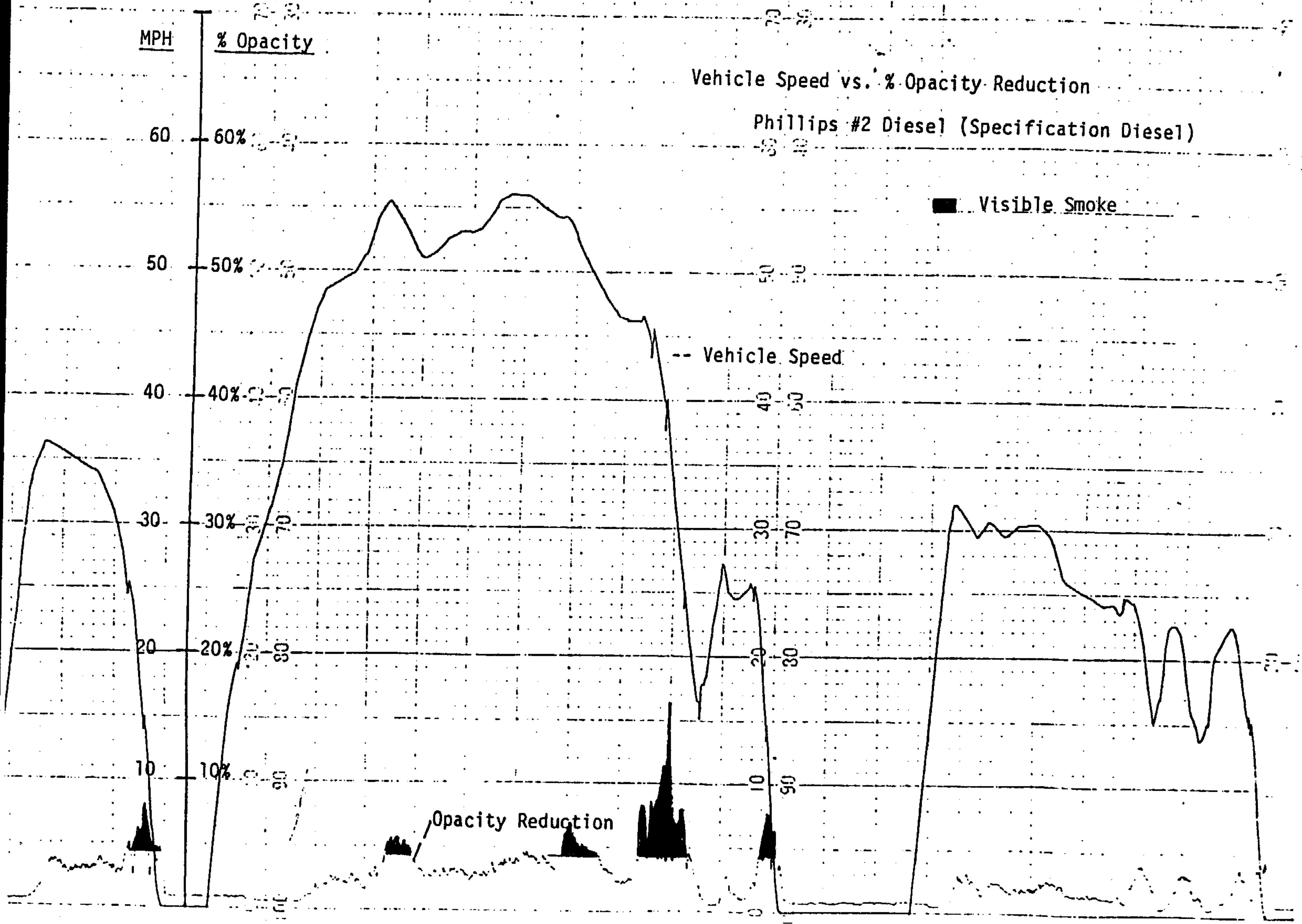
Laboratory: Environmental Test Corporation, Aurora, Colorado

Test: "74" Hot (2 Phase/2 bag) Test to EPA Standards

Emission	Phillips #2 Diesel (Specification Diesel) (gr/mile)	Rentech Diesel (gr/mile)	%
Particulates	.1815	.1176	64.79%
Hydrocarbons (HC)	.229	.107	46.72%
Carbon Monoxide (CO)	1.049	.617	58.82%
NOx	1.043	1.029	98.66%
SOx	(1)	(1)	0.00%
		AVERAGE	53.80%

(1) Not measured by test, however Rentech Diesel has no detectable sulphur.


Vehicle Speed vs. % Opacity Reduction
Rentech Diesel
MPH
% Opacity
60
50
40
30
20
10
60%
50%
40%
30%
20%
10%
Visible Smoke
-- Vehicle Speed
Opacity Reduction


MPH
% Opacity
Vehicle Speed vs. % Opacity Reduction
Phillips #2 Diesel (Specification Diesel)
Visible Smoke
-- Vehicle Speed
Opacity Reduction
60
60%
50
50%
40
40%
30
30%
20
20%
10
10%

9/7/89

PARTICULATE EMISSION SUMMARY
(gm/bhp-hr)

#1 Diesel

	Total	=	Volatile (lube oil)	+	Non Volatile (Fuel Related)
Detroit Diesel Test	.326	=	.174	+	.152
Less:					
Lube Oil(1)	(.135)	=	(.135)	+	0
Fugitive(2)	(.025)	=	0	+	(.025)
Fuel Related Emissions	.166	=	.039	+	.127

Rentech Diesel

	Total	=	Volatile	+	Non Volatile
Detroit Diesel Test	.268	=	.177	+	.091
Less:					
Lube Oil(1)	(.135)	=	(.135)	+	0
Fugitive(2)	(.025)	=	0	+	(.025)
Fuel Related Emissions	.108	=	.042	+	.066

(1) Lube Oil Emissions are based upon general data gathered by SwRI on the DD6V92TA (Class VI) engine (the same model used by Detroit Diesel). The actual contribution to emissions from the lube oil on the Detroit Diesel test will most likely be different. This data is being obtained from Detroit Diesel by RTD. Volatile emissions primarily from lube oil per Detroit Diesel (9/6/89) were .12-.15 gm/bhp-hr.

(2) Data from SwRI paper entitled "Diesel Lube Oils-4th Dimension of Diesel Particulate Control." Value shown is order of magnitude only and is included for discussion purposes.

Comments:
- Soluble Organic Fraction (SOF) = Volatile Fraction
- Mutagenic activity usually a function of fuel aromatic content
- Amount of fuel SOF is a function of fuel boiling range. (In LDV it is tied to % of fuel with boiling point >640°F - SAE paper 811191)

Conclusion: Fuel related volatile emissions are a relatively small portion of the total volatile emissions. The Rentech Diesel (No. 2 diesel) on a fuel basis shows a significant reduction as compared to a No. 1 Diesel and with an appropriate timing adjustment further reduction can be obtained.

RENTECH, INC.

PRESENTATION TO:

CALIFORNIA ENERGY COMMISSION
TRANSPORTATION, TECHNOLOGY, AND FUELS OFFICE

Sacramento, California
November 12, 1991

RENTECH, INC.
1624 Market Street, Suite 300A
Denver, Colorado 80202
(303) 571-4158

RENTECH, INC.

(Renewable Energy Technology, Inc.)

Denver, Colorado

GENERAL INFORMATION

- **RENTECH PROCESS PROPRIETARY TECHNOLOGY**

- Conversion of natural gas to liquid hydrocarbons using chemical process steps

- Certain aspects of the conversion process are unique and proprietary

- Catalyst used in conversion process is proprietary

- **PROCESS FEEDSTOCK SOURCES**

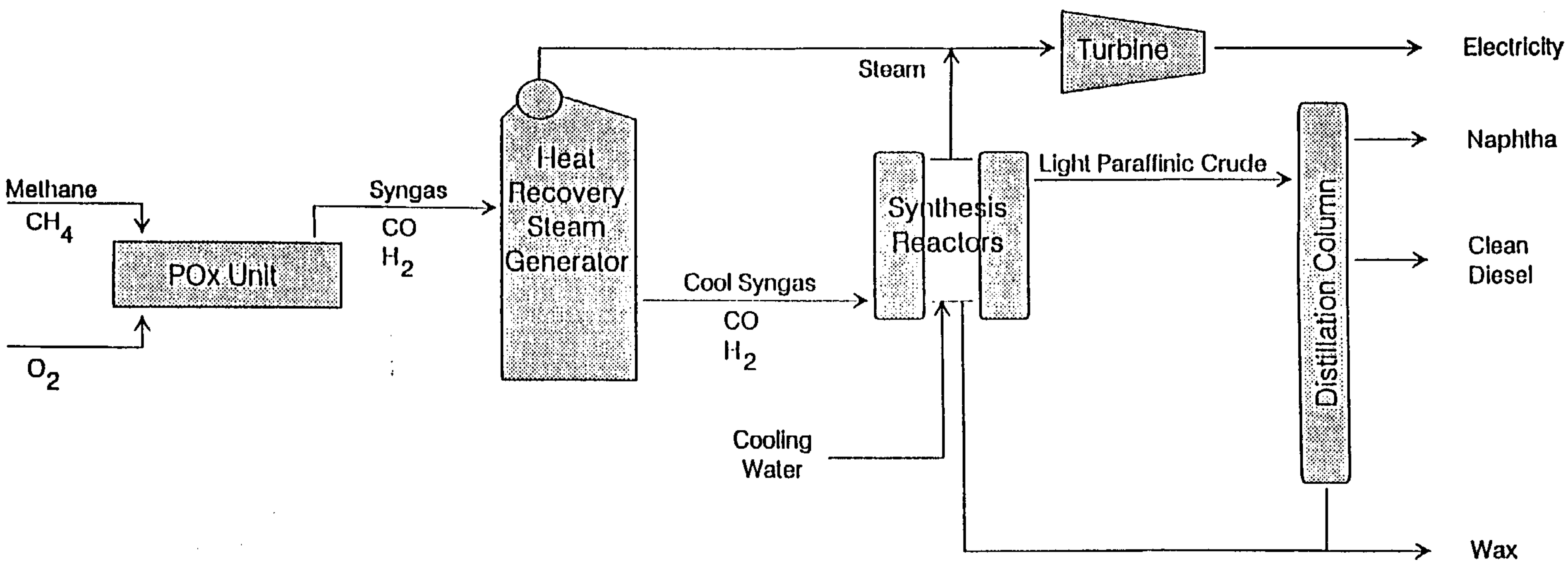
- Remote and shut-in natural gas

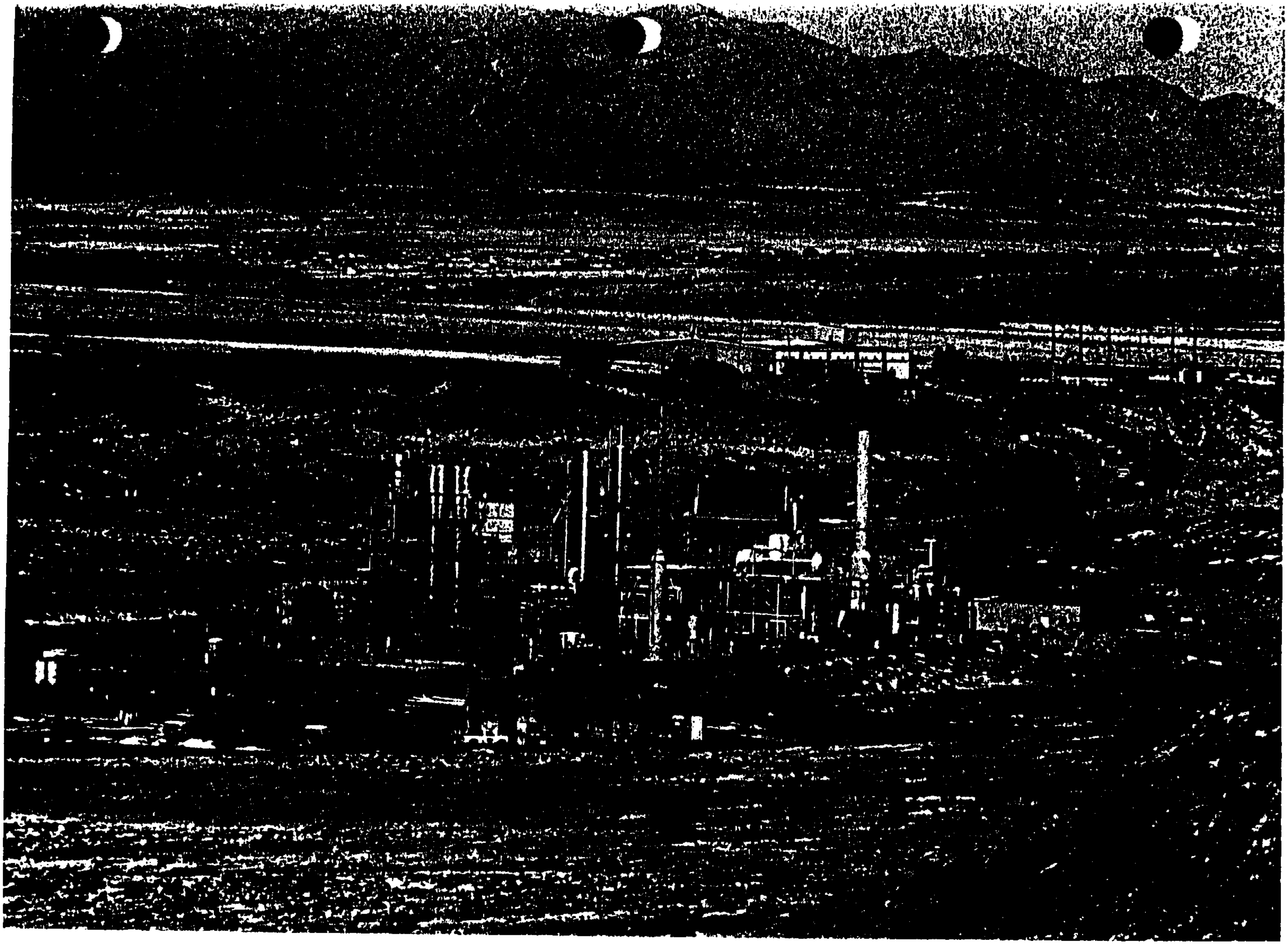
- Landfill gas

- Low energy content/low pressure gas

- Flared gas

Rentech Fischer-Tropsch Process





Synhytech Plant (November 1991)

PRODUCTS

- DIESEL
- WAX
- NAPHTHA/CHEMICAL FEEDSTOCKS

TESTS PERFORMED ON RENTECH DIESEL

Test Facility	Type of Test	Typical Data
Hauser Chemical Research, Inc. Boulder, Colorado	Fuel Test	viscosity, flash point, sulfur... (ASTM specs)
Environmental Testing Corporation Aurora, Colorado	Vehicle Test (74 "Hot")	emissions
California Air Resources Board El Monte, California	Vehicle Test (75 CVS)	emissions
Detroit Diesel Corporation Detroit, Michigan	Engine Test Heavy Duty Transient ("Hot")	emissions

COMPARISON of FUEL CHARACTERISTICS

Fuel Characteristics	NAS(1) RECOMMENDATIONS	TYPICAL COMMERCIAL	RENTECH
CETANE NUMBER, MIN.	>48	46	62
SULFUR, % WT. MAX.	<0.25%	0.35%	0.0%
90% DIST. PT.	<600°F	617°F	514°F
AROMATICS, % VOL.	<20%	33%	0.0%

(1) National Academy of Sciences, *Diesel Technology (1981)*

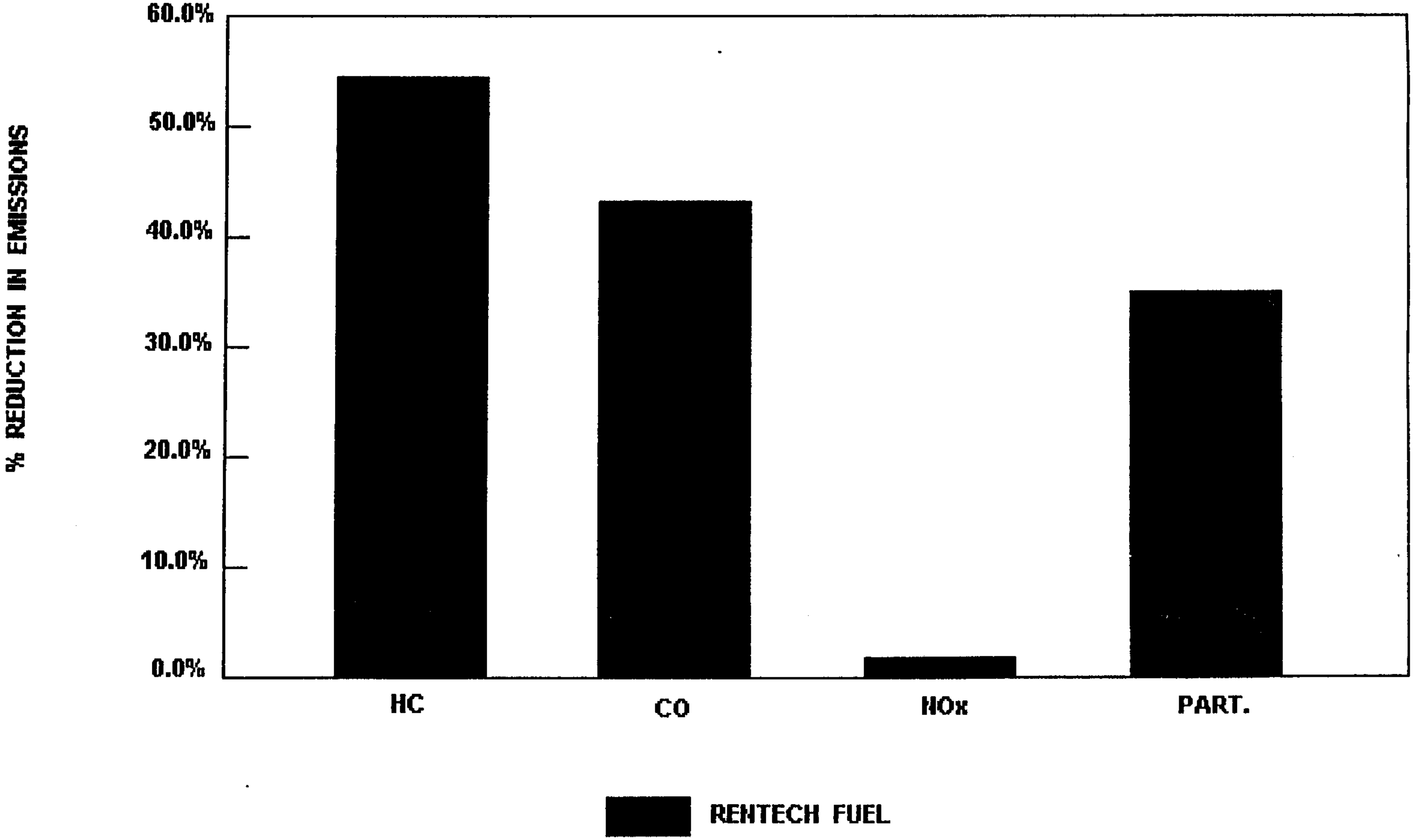
EMISSION RESULTS
High Altitude (ETC)
VW Quantum Turbo

	GR/MI			
	HC	CO	NOx	PART.
BASELINE(1)	0.229	1.05	1.04	0.182
RENTECH	0.107	0.617	1.03	0.118
% REDUCTION from BASELINE	**53.3%**	**41.2%**	**1.0%**	**35.2%**

(1) Specification DF-2

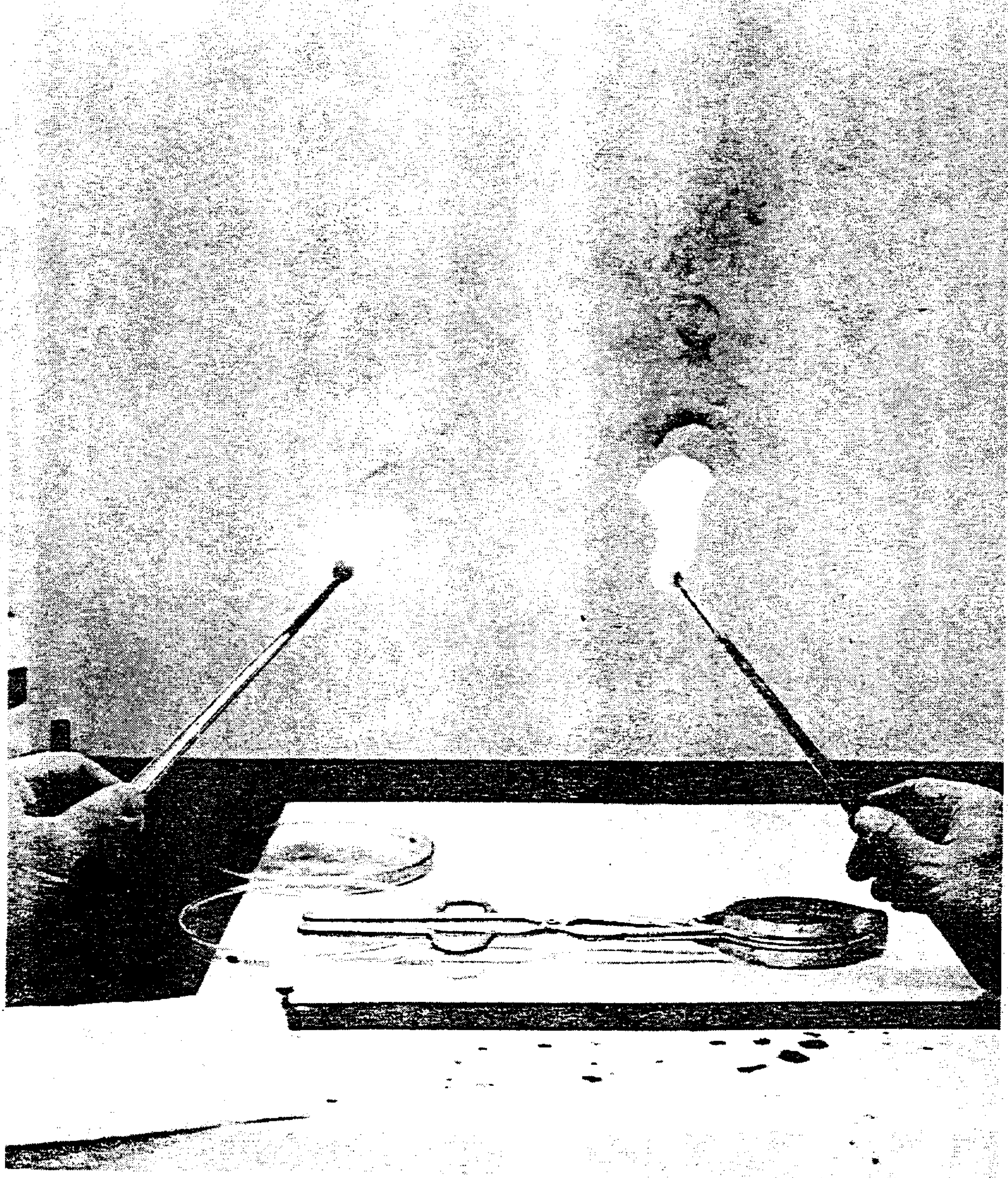
EMISSION RESULTS

High Alt. (ETC) - VW Quantum Turbo Diesel

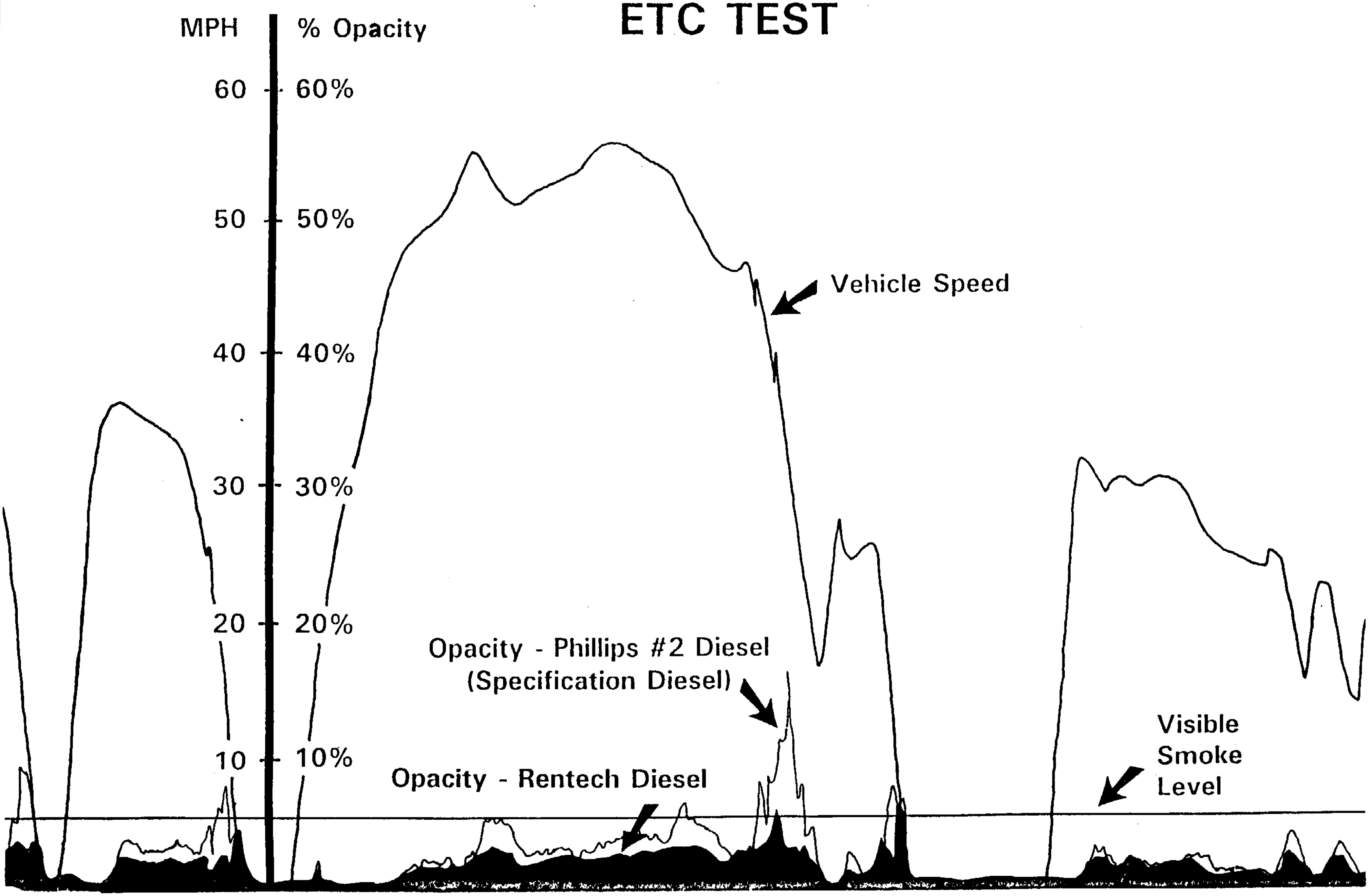


COMPARISON OF FUEL SMOKING CHARACTERISTICS

[illegible] wick on right is emitting [illegible] more smoke than [illegible] on left.



VISUAL SMOKE
ETC TEST



EMISSION RESULTS
Sea Level (CARB)
GMC Sierra 6.21 DDA

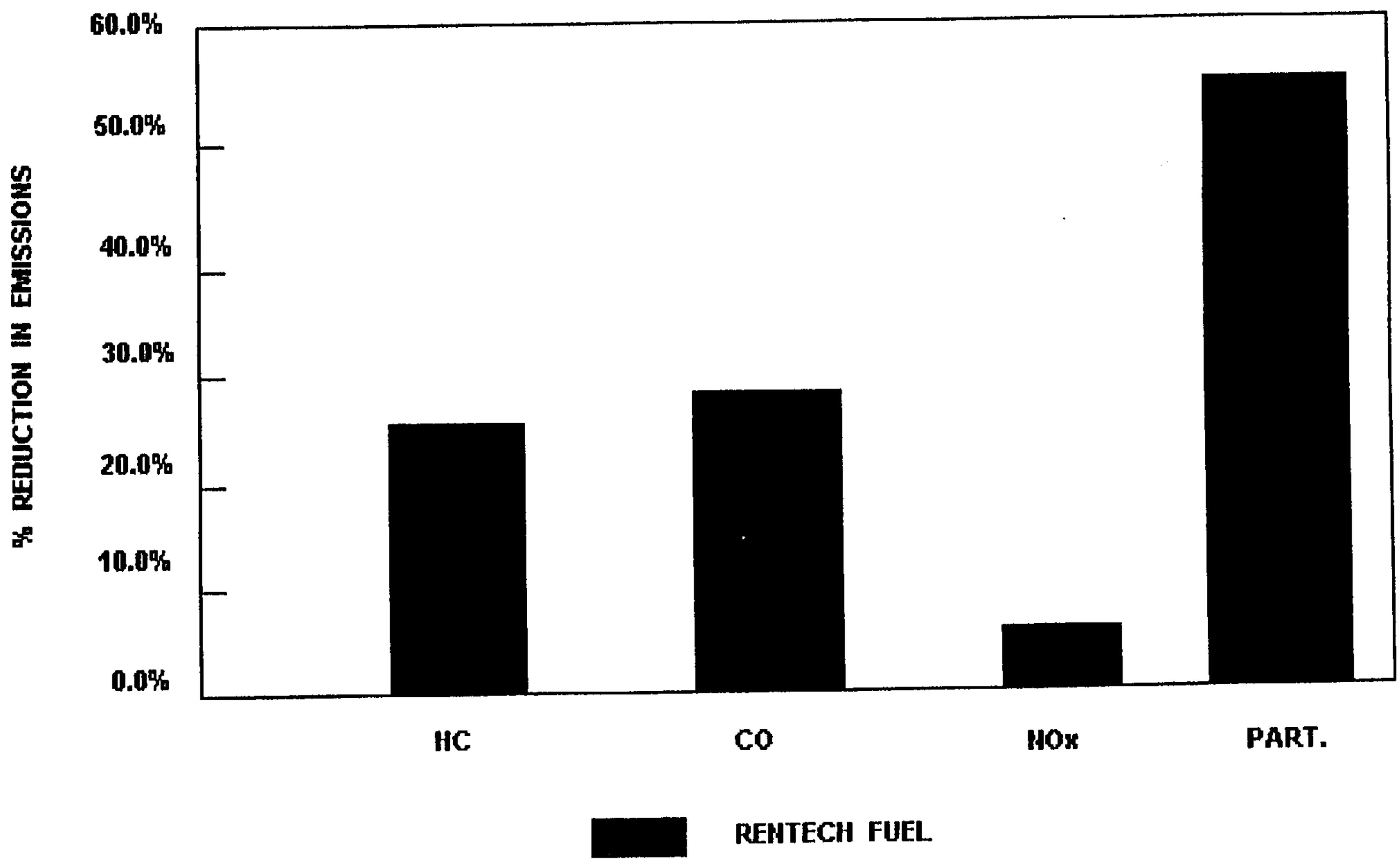
GR/MI

	HC	CO	NOx	PART.
BASELINE(1)	0.24	1.35	1.45	0.54
RENTECH	0.18	0.95	1.36	0.24
%REDUCTION from BASELINE	**25.0%**	**29.6%**	**6.2%**	**55.6%**

(1) Specification DF-2

EMISSION RESULTS

Sea Level (CARB) - GMC Sierra 6.21 DDA



EMISSION RESULTS[1]
Detroit Diesel - 6V-92TA

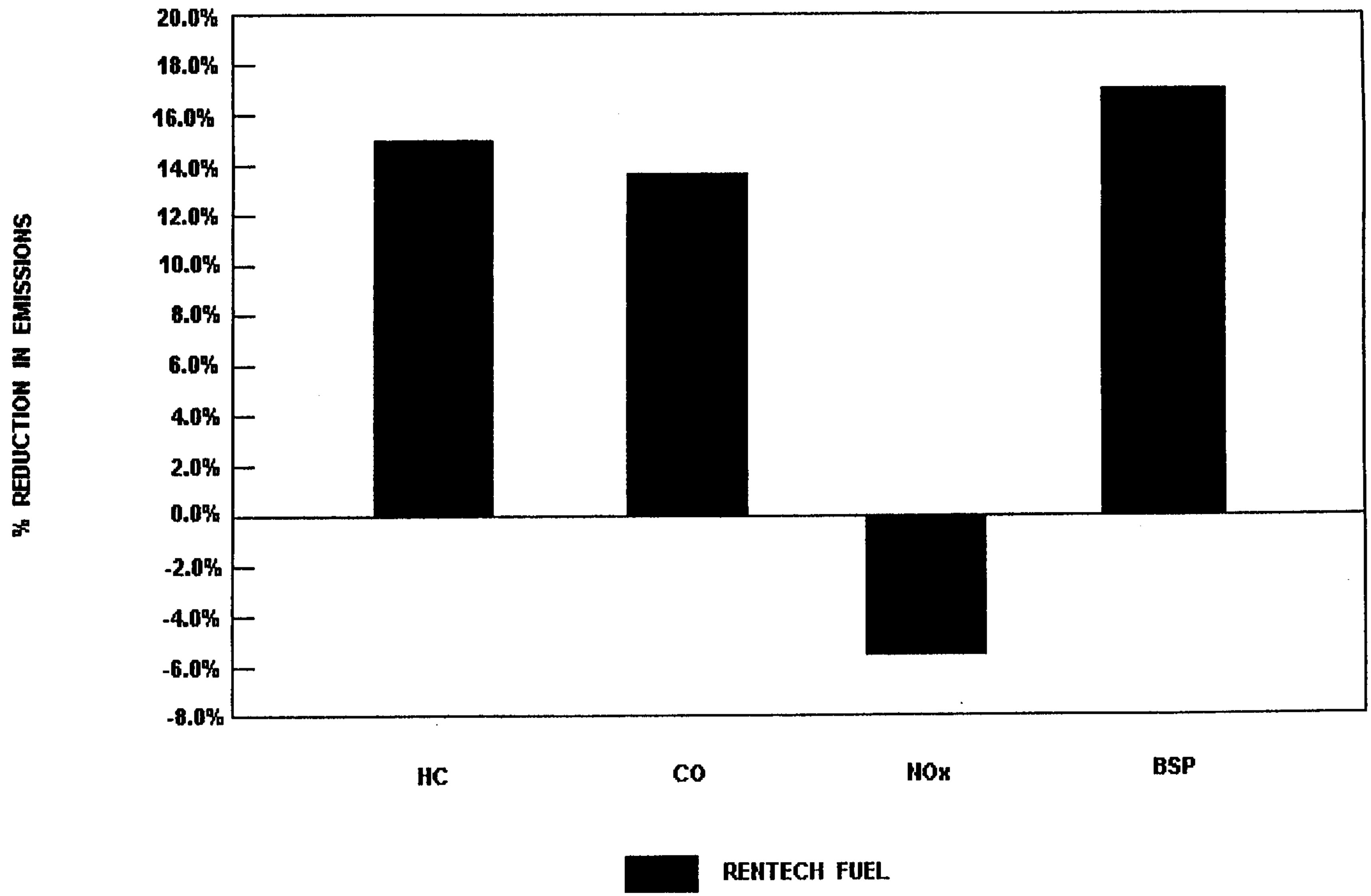
		GR/BHP-HR		
	HC	**CO**	**NOx**	**BSP**
BASELINE[2]	0.81	1.25	4.89	0.326
RENTECH	0.69	1.08	5.19	0.268
%REDUCTION from BASELINE	**14.8%**	**13.6%**	**-6.1%**	**17.8%**

(1) SAE Paper 91235 *Toward Improved Diesel Fuel*

(2) DF-1 (low sulfur)

EMISSION RESULTS

Detroit Diesel - 6V - 92A



EMISSION RESULTS(1)
Detroit Diesel - 6V-92TA

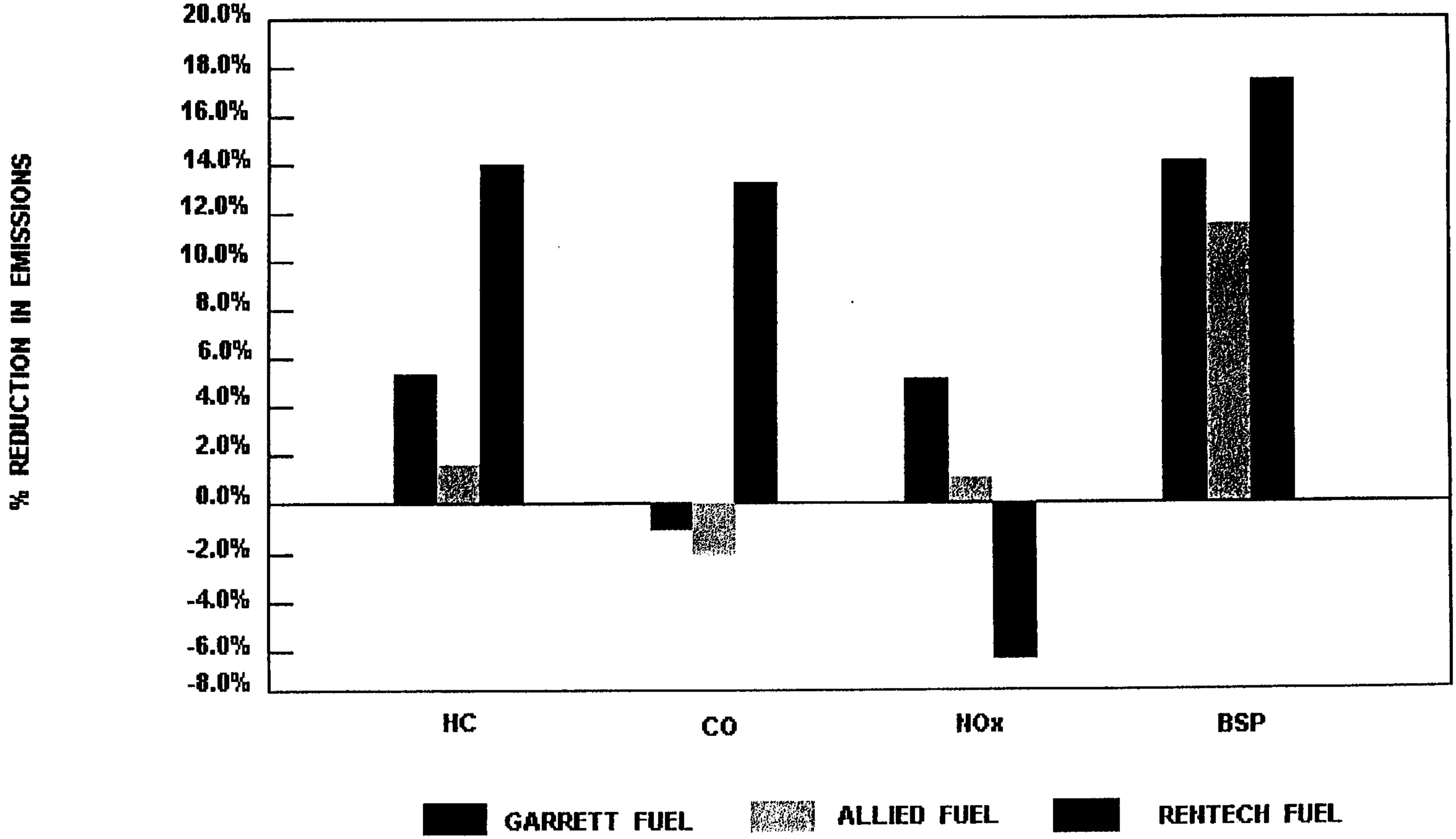
	GR/BHP-HR			
	HC	CO	NOx	BSP
BASELINE(2)	0.67	1.42	4.64	0.227
GARRETT	0.63	1.44	4.4	0.195
ALLIED	0.66	1.45	4.59	0.201
<u>% REDUCTION from BASELINE</u>				
GARRETT	6.0%	-1.4%	5.2%	14.1%
ALLIED	1.5%	-2.1%	1.1%	11.5%

(1) SAE Paper 91235 *Toward Improved Diesel Fuel*

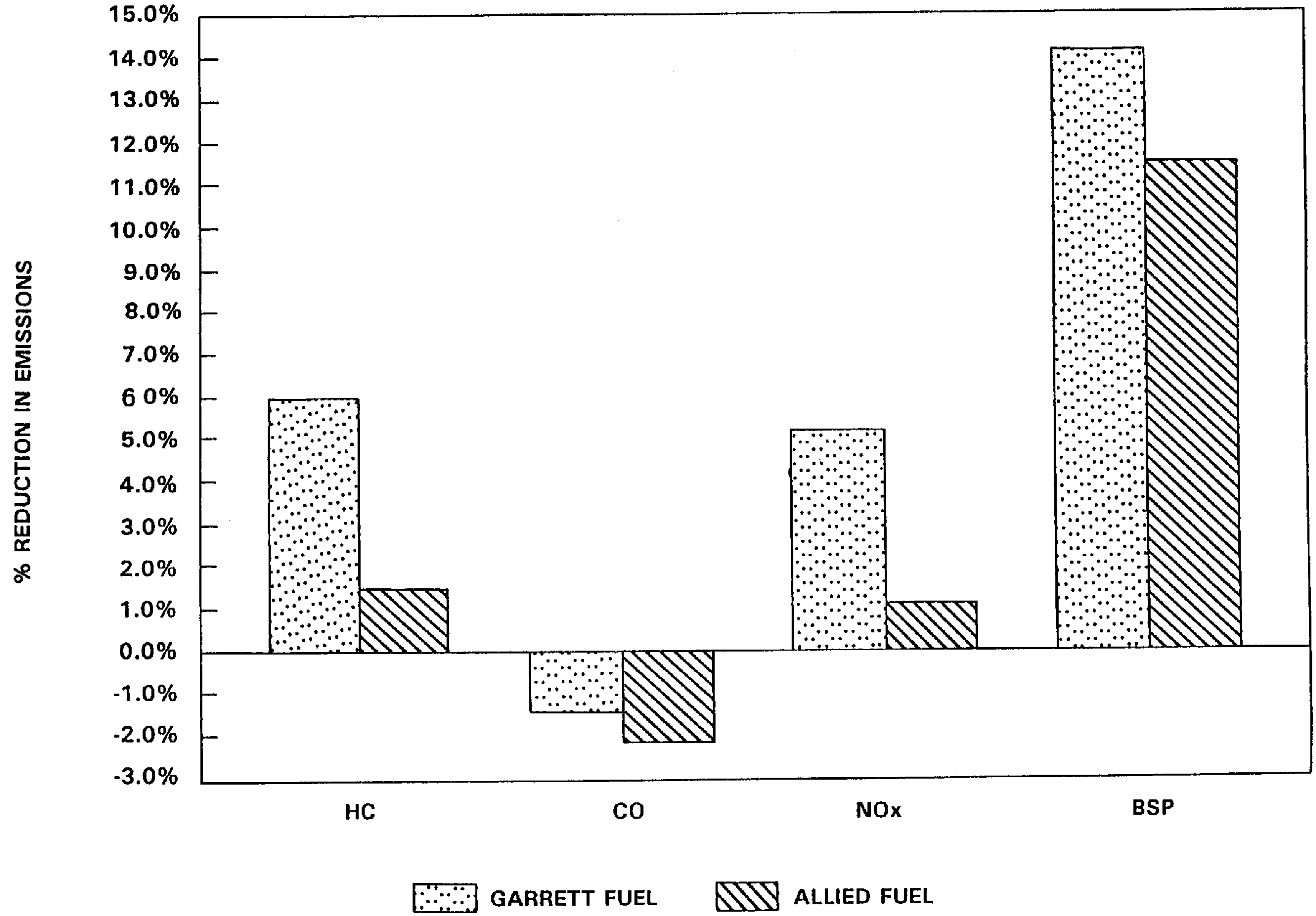
(2) DF-1 low sulfur (0.1%)

EMISSION RESULTS

Detroit Diesel - 6V - 92TA



EMISSION RESULTS
Detroit Diesel - 6V-92TA



COMPARISON of FUEL CHARACTERISTICS

Fuel Characteristics

	NAS(1) RECOMMENDATIONS	TYPICAL COMMERCIAL	RENTECH	ALLIED	GARRETT
CETANE NUMBER, MIN.	>48	46	62	53	45
SULFUR, % WT. MAX.	<0.25%	0.35%	0.0%	0.0%	0.0%
90% DIST PT.	<600°F	617°F	514°F	475°F	450°F
AROMATICS, % VOL.	<20%	33%	0.0%	12%	<1%

(1) National Academy of Sciences, Diesel Technology (1981)

DIESEL SPECIFICATIONS

	No. 1 Diesel	No. 2 Diesel	RENTECH DIESEL Straight Run	RENTECH DIESEL "Cracked" Product
	ASTM	ASTM		
CETANE INDEX	45 min	40 min	62	73
SULFUR WT. %	.50 max	.50 max	<0.0001*	<0.0001*
90% DISTILLATION TEMPERATURE	---- 550°F-max	540°F-min 640°F-max	566°F	653°F
VISCOSITY @ 40°C cSt.	1.4 min 2.5 max	1.9 min 4.1 max	1.8	2.49
FLASH POINT °F, MIN	100°F	125°F	122°F	138°F
AROMATIC CONTENT, VOL %	8% min	33%	0%	0%
BTU/1b	16,000- 17,000	19,810	19,371	19,754
OXYGEN CONTENT, WT. %	N/A	N/A	3.05%	0.16%

* Analyses were below imits of detection.

(1) ASTM D975-81 #1 Diesel
(2) ASTM D975-81 #2 Diesel

RENTECH DIESEL SUMMARY

- MEETS OR EXCEEDS ALL ASTM SPECIFICATIONS
- NO SULFUR
- NO AROMATICS
- MAJOR REDUCTIONS IN HARMFUL EMISSIONS
- CONTAINS OXYGEN
- NO VEHICLE MODIFICATIONS REQUIRED

"A conventional fuel from unconventional sources"

EMISSION RESULTS
Sea Level (CARB)
GMC Sierra 6.21 DDA

	GR/MI			
	HC	CO	NOx	PART.
BASELINE(1)	0.24	1.35	1.45	0.54
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<u>%REDUCTION from BASELINE</u>	25.0%	29.6%	6.2%	55.6%

(1) Specification DF-2

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VW Quantum Turbo

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	HC	CO	NOx	PART.
BASELINE(1)	0.229	1.05	1.04	0.182
RENTECH	0.107	0.617	1.03	0.118
<u>% REDUCTION from BASELINE</u>	53.3%	41.2%	1.0%	35.2%

(1) Specification DF-2

MS-84-005

State of California
AIR RESOURCES BOARD

Emission and Fuel Economy Tests of Rentech Diesel Fuel

July 1984

Engineering Evaluation Section
Mobile Source Division
9528 Telstar Avenue
El Monte, California 91731

Report Number MS-84-005
Emission and Fuel Economy Tests
Rentech Diesel Fuel

By

MOBILE SOURCE DIVISION
State of California
AIR RESOURCES BOARD
9528 Telstar Avenue
El Monte, CA 91731

SUMMARY

Because of fuel characteristics which have potential for reducing diesel engine emissions, the Air Resources Board (ARB) agreed to test Rentech diesel fuel. The fuel is made using excess and/or waste natural gas as the raw feedstock, and, according to Rentech, can be made at a price competitive with diesel fuel. The fuel properties include a low aromatic content, low sulfur level, and a high cetane number. All of these characteristics contribute to lower emissions compared to diesel #2.

Initial limited emissions testing did show significantly reduced particulate emissions based on one set of back-to-back tests. Directionally, other gaseous emissions were also slightly lower, though additional testing would be necessary to confirm these initial observations.

Introduction

Rentech has developed a new process for producing diesel fuel using natural gas as the primary feedstock. At present, Rentech only has the capability of producing small quantities of the fuel for emission evaluation purposes. Once the emission performance of the fuel has been verified, facilities would be developed which Rentech believes would enable them to produce the fuel at competitive prices.

The ARB agreed to evaluate the fuel because its properties indicate a strong potential to achieve reduced particulate emissions when used in diesel engines. Emission tests were conducted by the Haagen-Smit Laboratory in July, 1984. This report presents the results of these preliminary tests.

Test Vehicle

Cal-Trans provided a new 1984 GMC Sierra 1500 Series 1/2 ton short bed pick-up truck with the following specifications:

- Engine - 6.2 liter DDA diesel Model PTC10703
- GVW - 4900 lbs.
- Odometer - 3100 miles, License E872454
- Transmission - Automatic 4 speed

In order to avoid contamination of the Rentech fuel with #2 diesel, the vehicle was fitted with a 5 gallon vented fuel can mounted in the truck bed complete with new supply and return fuel lines. A new fuel filter was also installed for the Rentech fuel tests.

Test Procedure

The vehicle was prechecked and scheduled for the following test sequence:

- Baseline tests with #2 Phillips Reference Fuel.
  Two FTP tests with particulate measurement.
  Two HWFET Tests

- Tests with Rentech Diesel Fuel
  One FTP test with particulate and aldehyde measurement
  One HWFET test
  One Ames Filter test

- Baseline tests with #2 Phillips Reference Fuel.
  One FTP test with particulate and aldehyde measurement.
  One HWFET Test
  One Ames Filter test.

Test Fuel Analysis

A fuel sample was taken from the limited quantity (4 gallons) of Rentech Diesel Fuel submitted for testing and was analyzed for HC species, distillation curve, calculated Cetane number, sulfur, and specific gravity.

Test Results

I. Analysis of Rentech Fuel

ARB lab analysis of the distillation curve, specific gravity, calculated cetane number, and sulfur content are shown in Appendix I.

ARB analysis of the HC species by weight percent of volume is shown in Appendix II.

A copy of Hauser Laboratories Chemical Research Inc. analysis of Rentech Diesel fuel and specifications for ASTM D975-81 #2 Diesel are also included in Appendix I for comparison.

II. Emission Test Data

The results of the exhaust emission and highway fuel economy tests are shown in Table I.

Discussion

Based on the limited data obtained from the one test series (there was not enough fuel to run two series), Rentech Diesel Fuel performance tends to support the manufacturer's claim of reduced particulates and emissions of HC, CO, and NO_x. There was no significant difference in aldehyde emissions. Although the claimed heat value of the Rentech fuel is higher than #2 diesel, the 10% lower carbon content per gallon resulted in approximately 10% lower fuel economy based on CVS fuel consumption calculations. Rentech Inc. is presently in the process of determining the optimum fuel injection timing to take advantage of the fuel's high cetane number and higher flame speed and is proposing an additional set of tests at the optimized timing. Rentech plans to set the timing to obtain maximum torque at the engine manufacturer's specified maximum torque speed. Rentech theorizes that the optimized timing will improve fuel economy and may result in lower emissions.

The Ames filter samples were sent to Southwest Research Institute for analysis.

Table I
Emissions Tests - 1984 GMC Sierra 1500 Series P.U.
6.2 Liter Diesel E872454

Test Date	Odometer	Test Fuel	Test Type			Emissions - grams/mile				Fuel Economy
				HC	CO	CO_2	NO_x	Part.	Aldehydes	MPG
7/6/84	3187	#2 Diesel	CVS-75	.25	1.34	508	1.45	.55	--	19.9
7/10/84	3216	"	Baseline	.21	1.28	524	1.50	.58	--	19.3
8/08/84	3322	"	"	.25	1.43	514	1.41	.59	.032*	19.7
Average				.24	1.35	515	1.45	.57		19.6
7/12/84	3241	Rentech	CVS-75	.18	.95	517	1.36	.24	.037**	17.6
7/6/84	3199	#2 Diesel	Highway Cycle	.10	.57	354	1.67	--	--	28.7
7/11/84	3231	"	"	.08	.59	367	1.69	--	--	27.7
7/18/84	3292	"	"	.11	.61	371	1.77	--	--	27.3
Average				.10	.59	364	1.71			27.9
7/12/84	3253	Rentech	Highway	.08	.46	356	1.50	--	--	25.5

* Consists of .0186 gms/mile formaldehyde, .0079 gms/mile Acetaldehyde and .0059 gms/mile Acrolein/Acetone

** Consists of .0216 gms/mile formaldehyde, .0086 gms/mile Acetaldehyde and .0066 gms/mile Acrolein/Acetone

APPENDIX I

MS-84-005

State of California
AIR RESOURCES BOARD

Emission and Fuel Economy Tests of Rentech Diesel Fuel

July 1984

Engineering Evaluation Section
Mobile Source Division
9528 Telstar Avenue
El Monte, California 91731

Report Number MS-84-005
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- Transmission - Automatic 4 speed

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6.2 Liter Diesel E872454

Test Date	Odometer	Test Fuel	Test Type	HC	CO	Emissions - grams/mile CO_2	NO_x	Part.	Aldehydes	Fuel Economy MPG
7/6/84	3187	#2 Diesel	CVS-75	.25	1.34	508	1.45	.55	--	19.9
7/10/84	3216	"	Baseline	.21	1.28	524	1.50	.58	--	19.3
8/08/84	3322	"	"	.25	1.43	514	1.41	.59	.032*	19.7
Average				.24	1.35	515	1.45	.57		19.6
7/12/84	3241	Rentech	CVS-75	.18	.95	517	1.36	.24	.037**	17.6
7/6/84	3199	#2 Diesel	Highway Cycle	.10	.57	354	1.67	--	--	28.7
7/11/84	3231	"	"	.08	.59	367	1.69	--	--	27.7
7/18/84	3292	"	"	.11	.61	371	1.77	--	--	27.3
Average				.10	.59	364	1.71			27.9
7/12/84	3253	Rentech	Highway	.08	.46	356	1.50	--	--	25.5

* Consists of .0186 gms/mile formaldehyde, .0079 gms/mile Acetaldehyde and .0059 gms/mile Acrolein/Acetone

** Consists of .0216 gms/mile formaldehyde, .0086 gms/mile Acetaldehyde and .0066 gms/mile Acrolein/Acetone

APPENDIX I

DIESEL FUEL TEST REPORT

PROJECT NO.: 2F84E2

Sample Identification: Synthetic Diesel Fuel

Sample Source: Rentech Corporation

Date Submitted or Obtained: May 15, 1984

SUMMARY OF TEST RESULTS

TYPE OF TEST		RESULT		TESTED BY	DATE
1. TOTAL PARTICULATE MASS -		—	grams/mile		
2. CALC. CETANE INDEX NO. -		71.11		fh	5-15-84
3. GRAVITY, API @ 60°F -		50.3	API°	"	"
4. VISCOSITY, centistokes -			cst		
5. FLASH POINT, °F -			°F		
6. DISTILLATION TEMP. AT:	IBP	385	°F	fh	5-15-84
	5%	409	°F		
	10%	418	°F		
	20%	430	°F		
	30%	443	°F		
	40%	457	°F		
	50%	476	°F		
	60%	496	°F		
	70%	518	°F		
	80%	546	°F		
	90%	578	°F		
	95%	599	°F		
	FBP	614	°F		

Recovery Volume: - 98.2 %

Residue Volume: - 1.5 %

Loss Volume (Observed) - Ø.3 %

Loss Volume (Corrected)- Ø.3 %

Sulphur: <0.01 wt.%

PETROLEUM PRODUCTS DISTILLATION
(ASTM-D 86)

PROJECT NO. 2F84E2 TEST NO. 1 TEST DATE 5-15-84 TIME 8:00 AM.

SAMPLE IDENTIFICATION: Synthetic Diesel Fuel

SOURCE: Rentech Corporation DATE OBTAINED: 5-04-84

BAROMETRIC PRESSURE: 752.6 mm Hg. AMBIENT ROOM TEMPERATURE: 73 °F

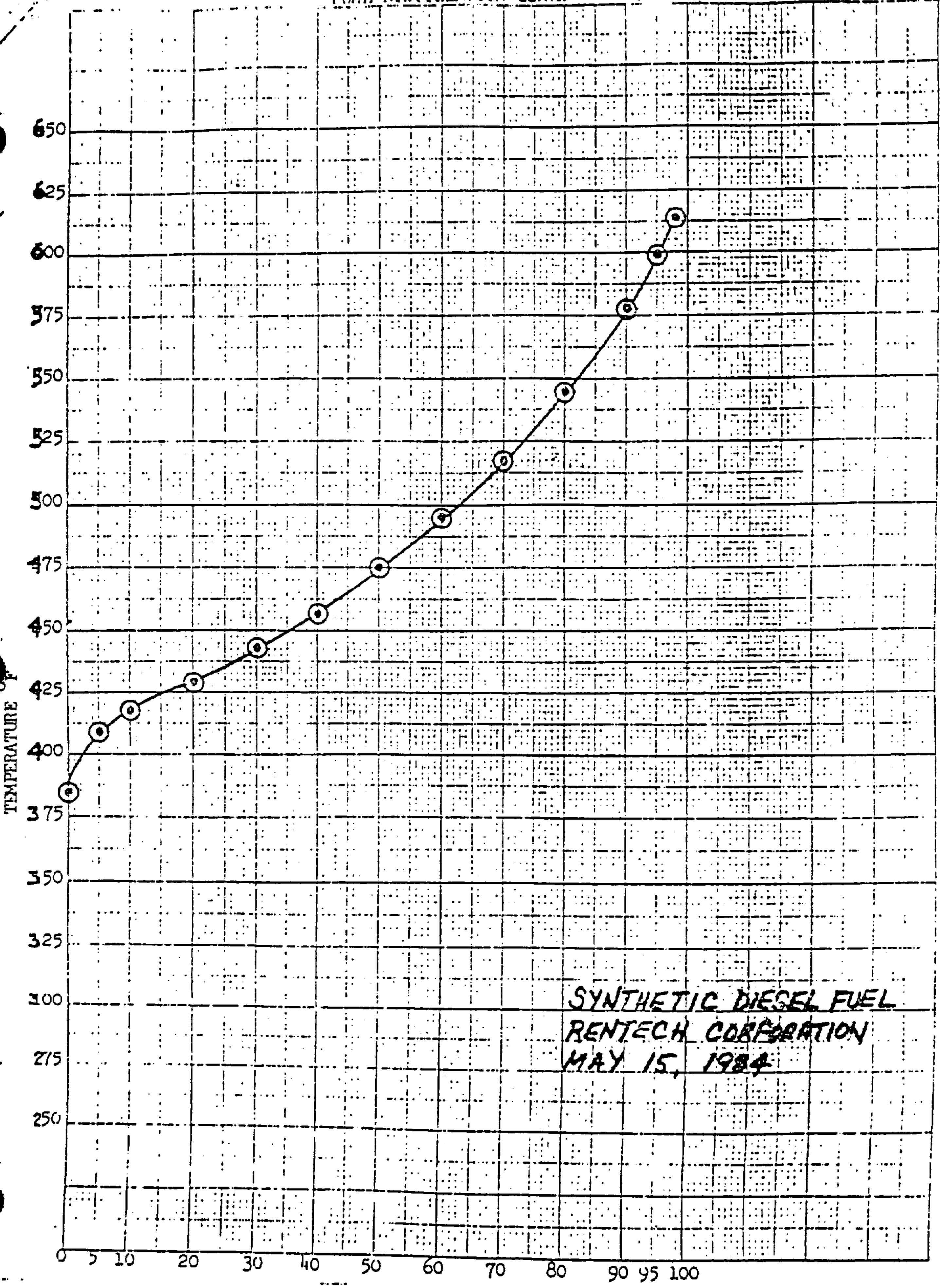
TEST DATA AND RESULTS

Time min:sec	Percent Recovered	Observed Temp. °F	Corrected Temp. °F	Temp. at Prescribed % Evap.	Average Temp. (of 2 tests)	Remarks
12:07	IP	384	385	385		
1:07	5	410	411	409		
1:06	10	418	419	418		
2:10	20	430	431	430		
2:14	30	443	444	443		
2:17	40	457	458	457		
2:19	50	476	477	476		
2:14	60	496	497	496		
2:16	70	518	519	518		
2:23	80	546	547	546		
2:15	90	578	579	578		
1:08	95	599	600	599		
3:07	EP	613	614	614		
	Recovery	98.2				
	Total Recovery	997				
	Loss (Observed)	Ø.3				
	Loss (Corrected)	Ø.3				

Calculated Cetane

°API = _______ @ _______ °F or °API = 50.3 @ 60°F Index No. 71.11

FUEL DISTILLATION CURVE



20 January 1984

Project: 1055

Rentech, Inc.
1620 Market Street, Suite 401
Denver, CO 80202

Attention: Mr. Charles B. Benham, Vice President, R&D

Description of Work

Approximately 10 gallons of sample provided was distilled to produce diesel range cuts. After measuring flash point and viscosity of selected cuts a blend was prepared and diesel spec tests, BTU value, FIA tests, and Bromine Number were performed. Results are tabulated below.

TEST	METHOD	RESULTS	Specifications ASTM D975-81 Diesel #2
Heat of Combustion BTU/lb	ASTM D240-76	20,646	
Flash Point, deg. F. (corr. to 760 mmHg)	ASTM D56-79	171	125 deg. F. min.
Specific Gravity @ 60/60 F.	ASTM D287-82	0.7753	
API Gravity (corr. @ 60 deg. F.)	ASTM D287-82	51.0	
Sulfur % by wt.	ASTM D129-64	<0.01	0.50% max.
Ash % by wt.	ASTM D482-80	<0.001	0.01% max.
Carbon Residue on 10% residue, % by wt.	ASTM D189-81	<0.001	0.35% max.
Copper Corrosion	ASTM D130-80	No. 1a	No. 1 min./ No. 3 max.
Calculated Cetane Index	ASTM D976-80	73	40 min.

[illegible] Boulder, Colorado [illegible] [illegible]

Rentech, Inc.
Project: 1055
20 January 1984
Page 2

TEST	METHOD	RESULTS		Specifications ASTM D975-81 Diesel #2
Engler Distillation, deg. F. (corr. to 760 mmHg)	ASTM D86-82	% Record	Temp F.	
		IBP	367	
		5	406	
		10	415	
		20	429	
		30	440	
		40	454	
		50	474	
		60	495	
		70	523	
		80	554	
		90	588	540-640 deg F.
		FBP	605	
Kinematic Viscosity	ASTM D445-82	2.01		1.9-4.1 cSt. 2-3.2
*Saturates, % by vol.	ASTM D1319-82	90.3		
Olefins	ASTM D1319-82	5.8		
Aromatics	ASTM D1319-82	3.9		
*Bromine Number	ASTM D1159-77	22.6		

*The type of material we are evaluating for olefin concentration is such that the Bromine number will be low by 12%. A corrected Bromine Number for the diesel blend is 25.7. This suggests the FIA test (ASTM D1319) is in error. The aromatic concentration is probably a maximum. Instrumental methods will have to be used to determine the exact aromatic concentration. The total olefin concentration in the diesel blend is 31.5 mole %. This value is based upon an average molecular weight of 196. The distribution of saturates, olefins, and aromatics is probably close to 64.6% saturates, 31.5% olefins and 3.9% ~~olefins~~. aromatics

Diesel Yield, as blended: 46.0%

Sample

45.96 Kg of natural gas derived crude was received in four 5 gallon gasoline cans. These cans were blended and the composite assigned HCR 8401-091-1055.

Intermediate Results

Some tests were run in preparation for blending. The results of those tests are listed below.

Flash Point, cut 7	96 deg. F.
Flash Point, cut 8	117 deg. F.
Flash Point, cut 9	141 deg. F.
Flash Point, cut 10	195 deg. F.
Viscosity, cut 10	2.18 cSt. @ 40 deg. C.

Distillation

The distillation was run on a 2 inch, 30 tray Oldershaw column at a 2:1 reflux ratio. Pressure ranged from 631.5 mmHg to 635.9 mmHg. A summary of data is shown below. For more detail a copy of the actual run sheet is shown below attached.

CUT	OVERHEAD TEMPERATURE	CUT SIZE AS % OF CHARGE
Initial Boiling Point	22 deg. C.	-----
1	40 " "	0.9%
2	60 " "	2.5%
3	80 " "	1.5%
4	100 " "	4.1%
5	120 " "	5.9%
6	140 " "	6.7%
7	160 " "	6.9%
8	180 " "	7.3%
9	200 " "	7.2%
10	300 " "	31.1%
11	320 " "	4.1%
12	330 " "	3.6%

Bottoms were 13.0% of charge. Overall material balance was 94.6%

Some water was recovered in the first and second cut. Total amount of water was in range of 0.01% of charge. At a bottoms temperature of about 300 deg. C. some water appeared in the overhead. The most likely explanation for this is that high molecular weight alcohols were cracking in the pot to produce water and olefins. The production of water continued to the end of the distillation. The total amount of water produced in the latter part of the distillation was less than 5 ml.

When the distillation was stopped, there was some waxing apparent in the receiver. This was the 320-330 deg. C. cut. Room temperature was about 55 deg. F.

Tests conducted by:

Kurt Ammon
Scientist I

Tests supervised by:

Ronald J. Harkrader, Ph.D.
Manager, Petroleum Div.

APPENDIX II

HAAGEN-SMIT LABORATORY
ATMOSPHERIC TESTING
ORGANIC ANALYSIS

Subject: Diesel Fuel Analysis

Sample Code: 5F4HSF1

Analytical Method: GC/MS

Analyst: T.S. Yeung

Project #: MS-36-SHC

Sample Date: 5/15/84

Form: Liquid

Reference: File #805

ANALYSIS:

COMPOUND	PERCENT
n-Nonane ($C_9 H_{20}$)	<0.3
n-Decane ($C_{10} H_{22}$)	2
n-Undecane ($C_{11} H_{24}$)	9
n-Dodecane ($C_{12} H_{26}$)	11
n-Tridecane ($C_{13} H_{28}$)	10
n-Tetradecane ($C_{14} H_{30}$)	9
n-Pentadecane ($C_{15} H_{32}$)	7
n-Hexadecane ($C_{16} H_{34}$)	6
n-Heptadecane ($C_{17} H_{36}$)	6
n-Octadecane ($C_{18} H_{38}$)	5
n-Nonadecane ($C_{19} H_{40}$)	4
n-Eicosane ($C_{20} H_{42}$)	3
n-Heneicosane ($C_{21} H_{44}$)	1
n-Docosane ($C_{22} H_{46}$)	<0.2
Other alkanes (C10-C21)	14
Alkenes (C10-C21)	13

REMARKS:

Rentech diesel sample report date 5/25/84

DETROIT DIESEL
CORPORATION

August 18, 1989

Mr. Mark Hennesy
Public Service Company of Colorado
243 Lipan Street
Denver, CO 80223-1390

Dear Mark:

The Rentech fuel supplied to us was evaluated on a 6V-92TA coach engine using the hot portion of the Federal heavy-duty transient emission test. Hot cycles were chosen because they can be run sequentially without an engine cool down period between cycles and because the resulting emission values approximate the results from emission certification tests. Three hot cycles were obtained with both the baseline fuel, which was #1 diesel fuel, and the Rentech fuel. The results are presented below:

	HC	CO	NOx	Part.	Volatile
#1 Diesel Fuel Baseline (171 kW maximum power)					
	.80	1.27	4.91	.326	.176
	.82	1.26	4.89	.326	.171
	.81	1.23	4.87	.325	.176
average	.81	1.25	4.89	.326	.174
Rentech Fuel (162 kW maximum power)					
	.68	1.07	5.20	.261	.175
	.69	1.08	5.16	.268	.179
	.70	1.08	5.20	.276	.176
average	.69	1.08	5.19	.268	.177
Percent Change	-15%	-14%	+6%	-18%	+2%

It appears that the Rentech fuel significantly decreased the unburned hydrocarbons (HC), carbon monoxide (CO), and particulate emissions. The volatile portion of the particulate emissions was essentially unchanged, which indicates that the solid or sooty portion of the particulate was reduced substantially.

In summary, the Rantech fuel provided seems to be a good fuel for compression-ignition engines. Of course, its cost and availability must be considered when comparing it to alternatives such as low-sulfur diesel fuel and K-1 kerosene.

Sincerely,

Richard E. Winsor

Dr. Richard E. Winsor
Manager, Combustion & Emissions

cc: J. Bennethum
J. Fisher
D. Merrion
T. Tindall